Deliverable-7.4

Final dissemination, standardisation and exploitation activities report

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Synopsis:	This deliverable describes the work performed in WP7 during the last 12 months of the PRISTINE project, reporting on dissemination, standardization and exploitation activities executed by the partners both individually and jointly. The report mainly summarizes impact actions based on the major PRISTINE results as set by the consortium and individually by partners, with focus on exploitation and standardization activities,

and business prospects generated by the RINA research carried out in the project.

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Executive Summary

This deliverable describes the activities performed in Work Package WP7 during the final phase of the PRISTINE project. It contains detailed reports and updates on the activities related to dissemination (task T7.1), standardisation (task T7.2) and exploitation (task T7.3).

The document is structured into three main sections: section 1 describes the dissemination of project results, section 2 presents a report on the standardisation activities, and section 3 illustrates the updated exploitation plans and provides the business perspective of RINA results achived in PRISTINE project using Business Model Canvas (BMC) methodology.

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Acronyms

CSA	Coordination and Support Action
DIF	Distributed IPC Facility
EAB	External Advisory Board
ETSI	European Telecommunications Standards Institute
FIA	Future Internet Assemblies
FIRE	Future Internet Research and Experimentation
FN	Future Network
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
IETF	Internet Engineering Task Force
ICCRG	Internet Congestion Control Research Group
IG	Interest Group
IP	Internet Protocol
IRTF	Internet Research Task Force
ISG	Industry Specification Group
ISO	International Organization for Standardization
JTC	Joint Technical Committee
MoU	Memorandum of Understanding
NCRG	Network Complexity Research Group
NFV	Network Functions Virtualization
NFVRG	Network Functions Virtualization Research Group
NMRG	Network Management Research Group
PSOC	Pouzin Society
QoS	Quality of Service
R&D	Research and Development
RG	Research Group
RINA	Recursive InterNetwork Architecture
SDN	Software Defined Networking
SDO	Standards Development Organization
STREP	Specific Targeted Research Project
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
VNF	Virtual Network Functions
VNRG	Virtual Networks RG
WG	Working Group

WP	Work Package
ZOOM	Zero-touch Orchestration, Operations and Management

1. Introduction

This deliverable is the third and final version of the PRISTINE project dissemination and exploitation report. The deliverable reports the activities related to the planned impact assessment, engagement with the scientific, professional, standardisation communities, and the general public, aimed at generating maximum awareness of the RINA architecture, RINA stack and various tangible and intangible outcomes of the PRISTINE project. All of these activities have successfully fulfilled the planned project objectives and contributed to the achievement of PRISTINE project's KPI 6 to 11 as set in the DoW.

PRISTINE dissemination activities throughout the whole project have been carefully chosen to strengthen the RINA awareness in the scientific and industrial communities, with workshops, summer schools, demonstrations and seminars directed to researchers from academia and industry and to EC officials. These initiatives aimed at establishing the image of PRISTINE as the reference project for RINA implementation on Linux and setting the roots for potential follow up activities beyond the project, both in terms of research and potential commercialization and standardization (e.g. ETSI NGP). The project dissemination channels (website and Twitter account) have been periodically updated to keep the pace of results produced by technical workpackages, both in terms of RINA specifications, code development and stack performance. Publications in highly ranked conferences and submissions to scientific journals have further supported PRISTINE awareness in the scientific community and stimulated a number of networking events with international organizations among those particularly interested in RINA and PRISTINE results. The team also leveraged on an intense cooperation with companion EC-funded projects on RINA (namely ARCFIRE), thus implementing a good coverage and roadmapping of development efforts for RINA functionalities in the open source stack http://irati.github.io/stack/.

Regarding standardisation, PRISTINE has started leveraging on the presence of key partners within Standards Development Organisations (SDOs) to raise awareness of the project and introduce relevant project foreground where possible. The RINA core specifications have been discussed with the members of the Pouzin Society (PSOC). A group of PRISTINE partners, in common with the IRATI project, has also promoted

the RINA architecture within ISO JTC1 SC6 WG 7 (Future Network) and two partners (iMinds and i2CAT) have undertaken a process of continuous enrollment in ISO to further progress these activities. Moreover, in 2016 TID and i2CAT contributed to the creation of the ETSI Industry Specification Group on Next Generation Protocols (ETSI NGP), to which also Nextworks joined at the end of 2016. RINA is one of the NGP solutions beyond TCP/IP under discussion in ETSI NGP.

In terms of exploitation, the consortium has worked towards identifying a set of research assets and results/outcomes from the project, analyzing potentials and initial strategies for further research, commercialization, business and societal impact. The methodology of Business Model Canvas has been used to structure and identify major directions to exploit PRISTINE foreground beyond the project lifetime. The continuation of PRISTINE developments through the IRATI open sources stack and the maintenance of that software on GitHub is an cornerstone of the PRISTINE exploitation strategy, both at project level and for individual partners. In fact, this is opening the RINA stack advanced by PRISTINE to re-use by a wide community of interested parties. In addition to that, some partners are setting preliminary steps towards the definition of RINA network products, thus advancing from the proof-of-concept stage to consolidated prototypes and potentail products (RINA router) for the market. In addition, MSc and PhD theses have been activated to sustain the huge amount of development work to be done on the different parts of the RINA architecture.

This document reports in detail all these elements, providing information on the strategy followed, and actions and plans carried out by the consortium to achieve impact.

2. Dissemination

PRISTINE has been an ambitious project that worked towards the development of new performance enhancing functions and protocols in a variety of research domains, including: DIF congestion control, distributed resource allocation techniques, topological addressing and associated routing mechanisms, strategies for authentication and access control, distributed DIF internal security mechanisms, support of multi-homing for load balancing and failure recovery, and multi-layer management (i.e. DIF configuration, performance, and security management in multi-layer systems).

PRISTINE's dissemination activities were planned to work in conjunction with the larger RINA roadmap. RINA already had a core community, but efforts have been made to grow the community and gain traction with external stakeholders. PRISTINE dissemination leveraged on its use cases and trials to help close this gap and present the technology on a larger stage:

- to extend beyond the core following of RINA and help catalyse community growth to other research communities, leveraging key results such as the SDK to facilitate further research.
- to help disseminate RINA research towards industry targets, translating the technological benefits of the architecture to business impact via market relevant use cases and trials, which such stakeholders need for further validation.
- to identify and disseminate to standards related groups that can act as conduits to further advance RINA's roadmap, leveraging PRISTINE results.

Significant efforts within the project have been devoted to disseminate the results obtained, using the different media available, which are the matter of the following sections. The dissemination activities presented in this document aims at highlighting the relevant activities undertaken by PRISTINE partners to pursue the highest visibility for project results, raise awareness about RINA among R&D communities, industry and relevant stakeholders.

The dissemination targets of PRISTINE include all sectors, institutions, organisations and individuals that are interested in the research carried

out in PRISTINE, that would contribute to its work, or that can affect or be affected by this research. Therefore, the target audience for the dissemination of project results was identified at the following levels:

- Corporate level. This is aimed at the industrial partners that will use the results and knowledge gained from the project within their companies. Internal dissemination targets can be found in the deliverable's partner exploitation plans. This level of dissemination also applies to the industrial members of the External Advisory Board (EAB).
- Consortium level. Intra-consortium dissemination enables all project partners to use and expand the technologies and tools developed within the project.
- Special communities. This is targeted at Interest Groups (IGs) and stakeholders who are directly related with the project. IG dissemination can provide a unique vehicle for project promotion and further exploitation. The project initially targeted the following groups: datacenter operators, network service providers and distributed application providers that implement their own communication overlays (e.g. p2p applications, Skype, etc.), since they are directly related to the project use cases and some consortium members have contacts with these communities. However, as the project has advanced, two new IGs have been added to the initial set:
  - *5G community*. 5G is a vision towards a set of capabilities that should provide a unified architecture for a fully converged network unifying mobile, wireless, sensor and fixed networks. Current research directions for 5G point to the investigation of a combination of virtualisation (both virtual networking and Network Functions Virtualisation, NFV), Software Defined Networking (SDN) and enhanced radio interfaces and radio resource management. However, no overarching network architecture that can fully realize the 5G vision for convergence has been proposed to date. RINA fits like a glove in a 5G scenario, as introduced in [rina5g]. Engagement of this IG benefits from common partners active in both PRISTINE and the 5G-PPP, a joint effort by the EC and the European telecom industry. As it will be explained later in this section, PRISTINE has already started to disseminate RINA to this IG.
  - *SDN and NFV community*. During the last year of the project PRISTINE has strengthened its ties to the SDN/NFV community, since the

trend towards network softwarization should facilitate understanding on RINA and raise interest on it amongst datacentre operators or network service providers. PRISTINE's final workshop in the SDN and OpenFlow World congress or the article in IEEE SDN Newsletter are examples of two actions performed in this direction.

- Wider research. PRISTINE's dissemination to wider network-related research communities is important to expand the existing core RINA community. This also reflects the adoption value of some of the project's primary assets, such as the SDK that helps alleviate the barrier of entry for newcomers to experiment with RINA.
- Wider public. While PRISTINE and RINA is rather technical in nature when reaching its primary stakeholders, the high-level benefits and impact can be translated to the wider public. Both industry vertical sectors and consumers can relate as the final beneficiaries / end-users in the telecom value chain.

2.1. Project brochure, leaflet and posters

During the third reporting period, the PRISTINE brochure was updated to reflect the project evolution and to highlight the applicability of PRISTINE research in a key technical topic for the EC: 5G technologies. The updated brochure has bee put online in the PRISTINE website [pristine-leaflet] and printed for dissemination in the target events that the project partners have attended.

A new poster was designed and printed for the TNC 2016 conference, explaining the main advantages of RINA for Network Management by discussing a multi-tenant large-scale Data Centre scenario, and providing details about the Network Management System demo performed in that event. The poster was displayed at the PRISTINE booth as well as at the conference poster's area [pristine-poster].

2.2. Project website and social networking tools

One of the aims of the dissemination task has been to ensure the broad external impact of the project. For this reason has been useful to identify the number of access users that navigate through the website. These statistics have been used as an indicator of the amount of interest in

the PRISTINE project. To implement this analysis we added the Google Analytics tracking code in the template of PRISTINE's website, enabling the tracking of statistics of the project's website. Figure Figure 1 shows a screenshot of the Audience overview of the Google Analytics web interface during the third period of the project (M19-M34).

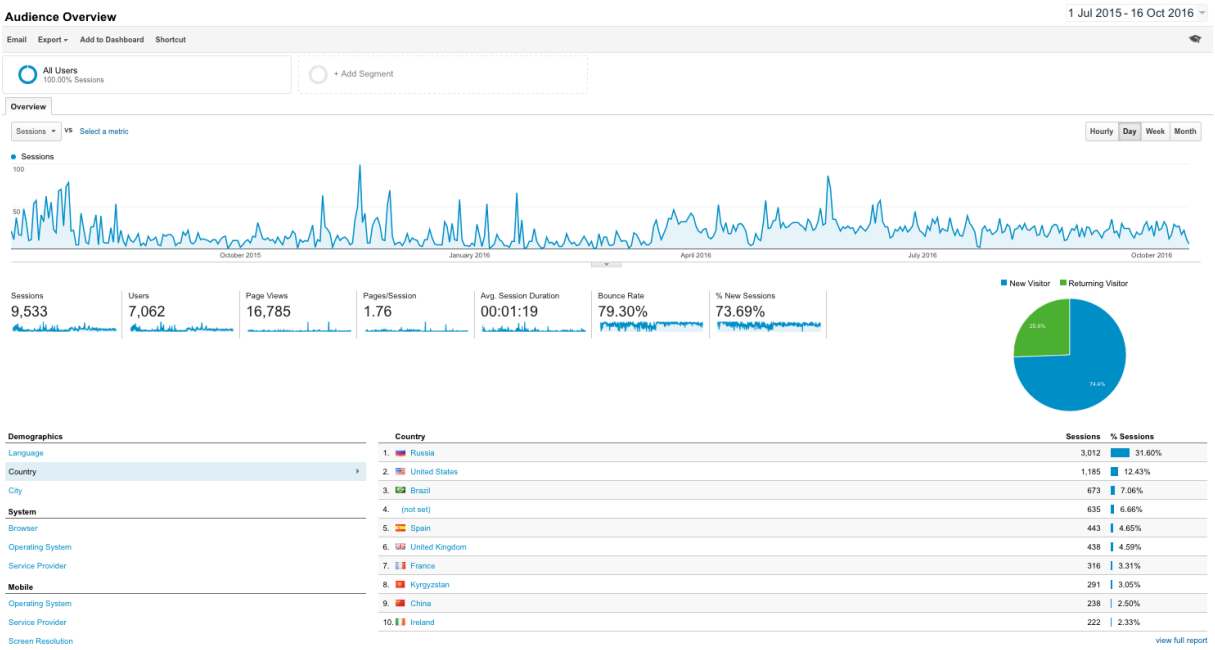

Figure 1. Statistics of visits to the PRISTINE website, July 2015 - October 2016

During the third period of the project (M19-M34) the number of sessions has multiplied by 1.5 and the number of visits by 1.2 with respect to the M10-M18 (illustrated in Figure 2), showing an increased interest in PRISTINE results. In terms of the origin of the visitors, 31.6% came from Russia, 12.4% came from the US, 7.1% from Brazil, 4.6% from Spain, 4.6% from the United Kingdom, 3.3% from France, and 3% from China. The spikes in visitors shown in the graph are mostly due PRISTINE presence in international events such as the booth at EUCNC 2015, the Broadband World Forum 2015, the PISA Internet Festival 2015, IEEE ICC 2016 or TNC 2016.

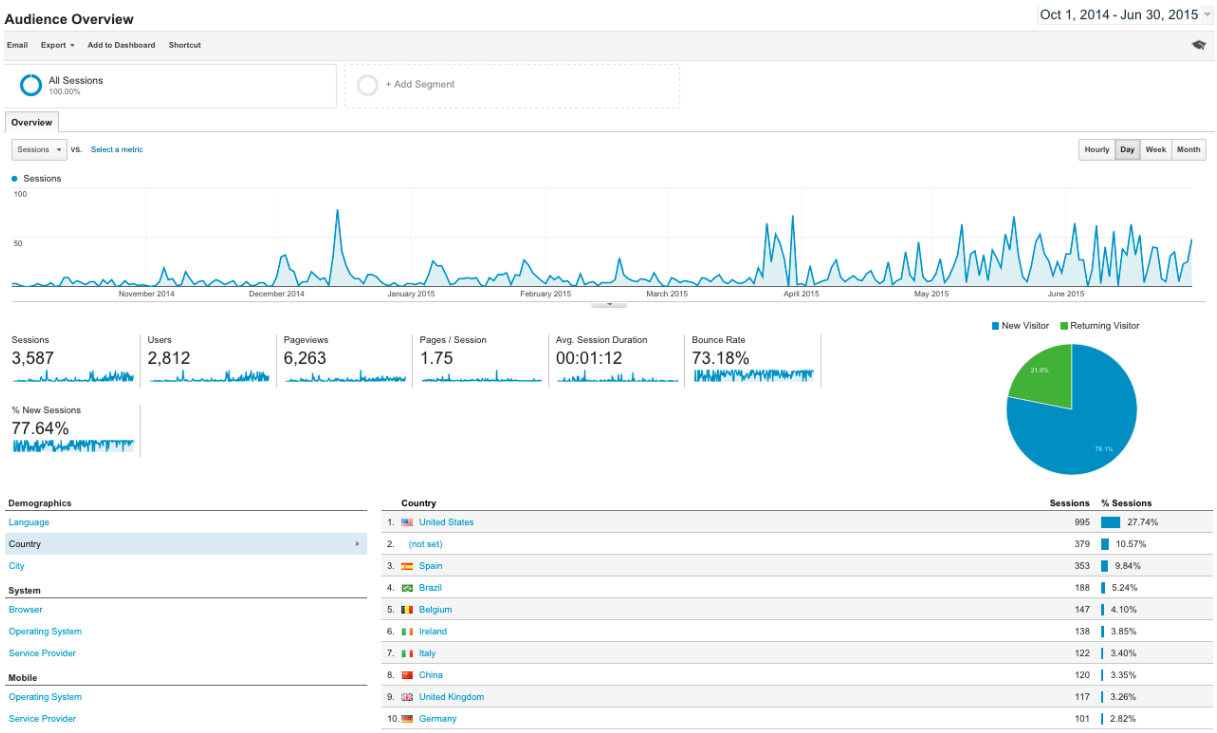

Figure 2. Statistics of visits to the PRISTINE website, October 2014 - June 2015

In order to improve the visibility of the research carried out, PRISTINE is making use of social networks. Thus, special accounts for the project in the Twitter [pristine-twitter] and Slideshare [pristine-slideshare] communities have been created. The project has used Twitter to post short messages relevant to the project's content, promote results and events. PRISTINE is right now followed by 126 users, which represents and increase of 100% compared to the previous reporting period (63 users in M18), and interacts with its followers usually on a bi-weekly basis. Table Table 1 shows the PRISTINE presentations available at Slideshare, when they were uploaded and the number of visualizations.

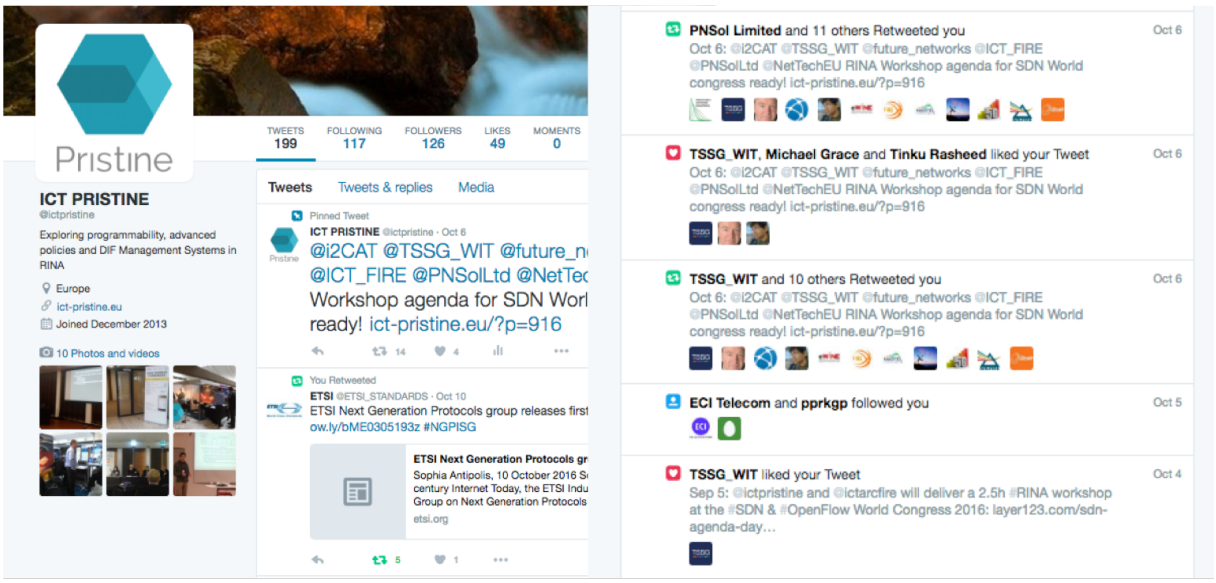

Figure 3. Screenshot of PRISTINE Twitter account, October 2016

Table 1. PRISTINE presentations online

Title	Upload date	# of visualizations
Pristine Intro SDN Concertation Workshop	February 2014	1123
RINA Tutorial to EC officers	June 2015	988
RINA as a Clean-Slate Approach to Software Networks	June 2015	882
EU-Taiwan Workshop on 5G Research, PRISTINE introduction	November 2014	836
PRISTINE @ FIA Athens 2014	April 2014	821
Latest advances from the PRISTINE project (GLIF 2015)	September 2015	726
PRISTINE presentation at the Net-Tech Future Coordination meeting	November 2014	689
RINASim Introduction	October 2015	539
IRATI: An open source RINA implementation for Linux/OS	September 2015	519
ICT Pristine Project Overview	February 2014	439
A software development kit to exploit RINA programmability (ICC 2016)	May 2016	410
From protecting protocols to layers (ICC 2016)	May 2016	389
Scalable Forwarding with RINA in distributed clouds	October 2016	369
Congestion control in Recursive InterNetwork Architectures (IETF 95)	May 2015	335
Congestion control in RINA (ICC 2016)	May 2016	315

Title	Upload date	# of visualizations
EUCNC RINA Tutorial slides	July 2016	252
RINA essentials (PISA Internet Festival)	October 2015	227
Brief introduction to RINA and PRISTINE	November 2014	223
Simplifying multi-layer networks with RINA	June 2016	203
EC Net Tech FI Cluster meeting October 23 2014 PRISTINE	December 2014	198
How to manage multi-layer networks	July 2016	163

PRISTINE presentations, tutorials and videos have been conveyed on SlideShare often to complement participation in events with a public access to project material. Another social media used by the project has been its blog, which can be accessed from the project site [pristine-homepage], as already presented in deliverable D7.1.

2.3. Publications in conferences and journals

As reported in Deliverable D7.2 and D7.3, a number of conferences and journals were identified as targets for submitting the project's research results worth disseminating. A significant number of these publications have been tried with results reported in the following.

2.3.1. Submitted publications

During the last period of the project (M19-M34) 27 articles have been submitted to journals, conferences and workshops, out of which 17 have been accepted, 6 have been rejected and 4 are under review. Regarding the rejected articles, the partners involved are already working (or plan to work) to improve them and try to submit to a different conference.

Article no. 1

Conference: 2nd OMNeT++ Community Summit[1]

Title: Skip This Paper - RINASim: Your Recursive InterNetwork Architecture Simulator

Submission: 10th June 2015

[1] https://summit.omnetpp.org/2015/

Abstract: Recursive InterNetwork Architecture is a clean-slate approach how to deal with the current issues of Internet based on traditional TCP/IP networking stack. Instead of fixed number of layers with dedicated functionality, RINA proposes a single generic layer with programmable functionality that may be recursively stacked. We introduce a brand new framework for modeling and simulation of RINA that is intended for OMNeT++.

Status: Accepted

Article no. 2

Conference: Network of the Future (NOF) Conference 2015[2]

Title: Scalable distributed clouds with RINA

Submission: July 2015

Abstract: This paper focuses on the specification of the addressing and routing functionalities of RINA, a clean-slate recursive inter-network architecture solving the weaknesses and limitations of the current TCP/IP. In particular, the main target of the paper is the distributed clouds, one of the RINA use cases envisioned in the FP7 PRISTINE project[1]. The paper reviews current distributed cloud system operation over TCP/IP, and analyses the benefits that RINA can provide to enhance its performance, as well as its scalability, a key constraint as the number of users raise up. Furthermore, several distributed cloud solutions based on RINA are proposed and their benefits highlighted.

Status: Rejected

Article no. 3

Conference: Network of the Future (NOF) Conference 2015[3]

Title: SFR: Scalable Forwarding with RINA for Distributed Clouds

Submission: July 2015

Abstract: Distributed clouds have been regarded as the key enabling technology to provide new trends of services. The contribution of this

[2] http://www.network-of-the-future.org/
[3] http://www.network-of-the-future.org/

paper is twofold. First, we discuss current distributed clouds architecture and highlight the issues involved, specifically scalability. Second, we investigate the benefits of the use of the Recursive InterNetwork Architecture (RINA) as a networking solution for the distributed clouds. Our proposal, called Scalable Forwarding with RINA (SFR), has been evaluated via simulations and showed to reduce the routing table size by around 31%. The paper concludes by highlighting the advantages of the RINA-based approach over current distributed clouds networking solutions in terms or scalability, simplicity and manageability.

Status: Accepted

Article no. 4

Conference: ICTON 2015[4]

Title: On the benefits of RINA over programmable optical networks for dynamic and smart resource management

Submission: July 2015

Abstract: In this paper, we describe the basics of the Recursive InterNetwork Architecture (RINA) and its advantages as a packet transport technology over programmable optical networks. In particular, its seamless integration over an SDN-controlled network infrastructure and its intrinsic capability of providing QoS is analysed and further discussed.

Status: Accepted

Article no. 5

Conference: Conference on Network and Service Management 2015 (CNSM 2015)[5]

Title: SFR: Dynamically Adaptive Policies for Dynamically Adaptive Telecommunications Networks

Submission: September 2015

Abstract: New technologies are changing the world of communication networks and even more so their management. Cloud computing and

[4] http://www.icton2015.hu/
[5] http://www.cnsm-conf.org/2015/

predictive analytics have removed the need for specialized compute hardware and created products that continuously search for and find insights in management data. Virtualization of networks and network functions, SDN and NFV, are beginning to be mature enough for production networks resulting in much more flexible and dynamic networks. IoT and M2M traffic and new customer demands are driving new thinking and demands for 5G networks. Almost every aspect in the control and management of networks has seen new dimensions of flexibility and dynamicity, with the notable exception of the policies that drive them. This paper discusses the need to add adaptiveness to classic policies, describes a novel approach for adaptive policies, shows how adaptive policies will form part of future network frameworks and architectures, and finally discusses early use cases developed for mobile operators.

Status: Accepted

Article no. 6

Conference: IEEE Systems Journal[6]

Title: Identification of Threats and Security Risk Assessments for Recursive Internet Architecture

Submission: October 2016

Abstract: There are several types of attacks on network communications such as disrupting or blocking communication, intercepting, injecting fabricated packets, accessing and modifying the information. Here, for the first time the SecRAM, a recent security risk assessment methodology, is proposed to be systematically applied in a different context, i.e., to the network systems, specifically to an emerging recursive network architecture called RINA. It is used for identifying run-time threats, assessing the risks involved, and defining measures to mitigate them. The risk assessment is performed to: assess the impact and likelihood of occurrence of attacks relevant to the identified threats; evaluate the RINA design principles; and validate the built-in security enablers and the mitigation actions that are devised to combat such attacks. Resulting from this assessment, specific measures are proposed to further improve the cyber resiliency of the RINA network system, in securing its layers and

[6] http://www.ieeesystemsjournal.org/

components. The enhancement prevails through the utilization of multi-layered security controls or the increase in strength of security controls that are established for implementation purposes. We also demonstrate formal analysis of some of the security properties of RINA network architecture using ProVerif tool and the developed RINA Simulator. We apply the tool to create a formal model of a RINA network and the selected attacks that can be mitigated. The results of analysis are also provided.

Status: In review (3rd iteration)

Article no. 7

Conference: IEEE ICC 2016[7]

Title: Congestion Control in the Recursive InterNetworking Architecture (RINA)

Submission: October 2015

Abstract: RINA, the Recursive InterNetwork Architecture, is a novel "back to basics" type approach to networking. The recursive nature of RINA calls for radically different approaches to how networking is performed. It shows great potential in many aspects, e.g. by simplifying management and providing better security. However, RINA has not been explored for congestion control yet. In this paper, we take first steps to investigate how congestion control can be performed in RINA, and demonstrate that it can be very efficient because it is applied close to where the problem happens, and through its recursive architecture, interesting effects can be achieved. We also show how easily congestion control can be combined with routing, enabling a straightforward implementation of in-network resource pooling.

Status: Accepted

Article no. 8

Conference: IEEE ICC 2016[8]

Title: A software development kit to exploit RINA programmability

[7] http://icc2016.ieee-icc.org/
[8] http://icc2016.ieee-icc.org/

Submission: October 2015

Abstract: The Recursive InterNetwork Architecture (RINA) is a general architecture for all forms of computer networking, based on a single type of programmable layer that recurs as many times as required by the network designer. The recursion and programmability aspects of RINA are key to design flexible, heterogeneous networks while still bounding their complexity. In this paper we show how the programmability enabled by the RINA architecture can be exploited in practice by means of a Software Development Kit (SDK) developed for IRATI, the open source RINA implementation. A proof of concept validation of the SDK is carried out by experimenting with multiple policies in a distributed cloud network scenario.

Status: Accepted

Article no. 9

Conference: IEEE ICC 2016[9]

Title: From protecting protocols to layers: Designing, implementing and experimenting with security policies in RINA

Submission: October 2015

Abstract: Current Internet security is complex, expensive and ineffective. The usual argument is that the TCP/IP protocol suite was not designed having security in mind and security mechanisms have been added as add-ons or separate protocols. We argue that fundamental limitations in the Internet architecture are a major factor contributing to the insecurity of the Net. In this paper we explore the security properties of the Recursive InterNetwork Architecture, analyzing the principles that make RINA networks inherently more secure than TCP/IP-based ones. We perform the specification, implementation and experimental evaluation of the first authentication and SDU protection policies for RINA networks. RINA's approach to securing layers instead of protocols increases the security of networks, while reducing the complexity and cost of providing security.

Status: Accepted

[9] http://icc2016.ieee-icc.org/

Article no. 10

Conference: IEEE Design of Reliable Communication Networks (DRCN) 2016[10]

Title: Resilient link state routing in the Recursive InterNetwork Architecture

Submission: October 2015

Abstract: Resiliency of computer networks is a thoroughly researched subject, as it is important for a lot of services that communication is not disrupted for extended periods of time. The Recursive InterNetwork Architecture (RINA) is a computer network architecture that is based on the principle that networking is IPC and IPC only. Resiliency in RINA has not yet been researched in depth. In this paper we take some initial steps towards that goal. We first make some initial observations on resiliency in RINA. We then proceed by introducing a resilient routing policy for RINA, based on Loop-Free Alternates. Some initial results of the implementation of this routing policy are presented, which shows it is able to recover traffic at carrier grade requirements in the case of link failures.

Status: Rejected

Article no. 11

Conference: TERENA Networking Conference 2016[11]

Title: Simplifying management of multi-layer networks with RINA

Submission: November 2015

Abstract: Computer networks are made of multiple co-operating layers that perform different functions implemented by a diverse set of protocols. The current approach of one function per layer implemented via one or more protocols contributes to increasing the complexity of multi-layer network management systems, causing them to be more expensive, error-prone and less automated that they could be. RINA is a network architecture featuring a single type of layer that recurses as many times as needed by the network designer. This layer, called a DIF, provides Inter

[10] https://drcn2016.lip6.fr/
[11] https://tnc16.geant.org/

Process Communication (IPC) services over a certain scope and ranges of bandwidth, QoS and scale. This paper performs a comparative analysis in the complexity of managing an IP-based and a RINA-based large-scale multi-tenant data centre networks. Configuration management is the main target of the analysis although some hints on performance and security management are also provided. The analysis shows that the commonality built into the RINA architecture and the single type of recursive layer with a uniform API greatly reduces the complexity of the models the Network Management System (NMS) uses to understand the state of the managed network. RINA opens the door not to an unprecedented degree of automation in Network Management, enabling the NMS to perform sophisticated configuration changes in multiple layers of the network at once while minimizing the risk of causing service downtime.

Status: Accepted

Article no. 12

Conference: IEEE SDN Newsletter[12]

Title: SDN architectural limitations: towards a full software network vision

Submission: November 2015

Abstract: Analysis of SDN architectural shortcomings and how RINA could provide the building blocks for the simple and powerful software network of the future.

Status: Accepted

Article no. 13

Conference: IFIP Networking 2016[13]

Title: Assuring absolute QoS guarantees for heterogeneous services in RINA networks with ΔQ

Submission: December 2015

Abstract: With the increasing usage of cloud computing and dependence on a diverse set of distributed applications, users are reliant on consistent

[12] http://sdn.ieee.org/newsletter
[13] http://networking2016.univie.ac.at/

outcomes from a shared infrastructure. This drives the need for absolute QoS guarantees for heterogeneous communication requirements over shared networks. The Recursive Inter-Network Architecture (RINA) is a clean-slate programmable network model that provides full QoS support for current and new service requirements. In this work, we focus on evaluating the QoS provided by such polyservice RINA networks. This exploits the concept of ΔQ, providing a QoS framework able to guarantee predictable outcomes to heterogeneous data flows. Indeed, strict limits on the maximum experienced losses and delays (ΔQ) can be enforced through the smart utilization of traffic policing and shaping strategies, together with an analytical pre-dimensioning of the buffer sizes. Our targeted scenario is a backbone network that prioritizes communications among geographically-distributed datacentres using resources shared with best-effort background traffic. Results obtained with the RINASim simulation software show that a ΔQ-enabled RINA network can yield the desired absolute QoS guarantees to the assured traffic classes without negatively impacting the best effort traffic, as it is the case with current MPLS-based VPN solutions.

Status: Rejected

Article no. 14

Conference: Management of the Future Internet Workshop (ManFI) 2016[14]

Title: Towards Self-Adaptive Network Management for a Recursive Network Architecture

Submission: December 2015

Abstract: Traditionally, network management tasks manually performed by system administrators include monitoring alarms based on collected statistics across many heterogeneous systems, correlating these alarms to identify potential problems or changes to management policies and responding by performing system re-configurations to ensure optimal performance of network ser- vices. System administrators have a narrow focus of factors im- pacting network service provisioning and performance due to the heterogeneity and scale of generated underlying network

[14] http://www.manfi.org/

events. However, self-adaption principles are conceptual approaches for autonomously managing such complex distributed systems. Network management systems that harness such principles can dynamically and autonomously optimise the operation of network services, responding quickly to changes in user requirements and underlying network conditions. In this paper, we present a novel self-adaptive network management framework that takes advantage of a recursive network architecture for a simpler and more comprehensive application of ontologies, semantic web rules and machine learning to automatically adjust network configuration parameters to provide more optimal QoS management of network services. We demonstrate the applicability of the approach using a content distribution network (CDN) operating over such a recursive network architecture.

Status: Accepted

Article no. 15

Conference: 2nd International Workshop on Smart Grid Technology and Data Processing

Title: Smart networks for smart grids and smart cities; New network science: RINA and ΔQ

Submission: February 2016

Abstract: Smart grids, smart cities and the Internet of Things all require connectivity that is substantially more secure, resilient, predictable, scalable and efficient than packet networks are today. New approaches are required: here we consider the Recursive InterNetwork Architecture (RINA) and the quality attenuation calculus (ΔQ).

Status: Accepted

Article no. 16

Conference: IEEE Globecom 2016[15]

Title: Benefits of Programmable Topological Routing Policies in RINA-enabled Large-scale Datacenters

[15] http://globecom2016.ieee-globecom.org

Submission: March 2016

Abstract: With the proliferation of cloud computing and the expected requirements of future Internet of Things (IoT) and 5G network scenarios, more efficient and scalable Data Centers (DCs) will be required, offering very large pools of computational resources and storage capacity cost-effectively. Looking at todays' commercial DCs, they tend to rely on well- defined leaf-spine Data Center Network (DCN) topologies that not only offer low latency and high bisectional bandwidth, but also enhanced reliability against multiple failures. However, routing and forwarding solutions in such DCNs are typically based on IP, thus suffering from its limited routing scalability. In this work, we quantitatively evaluate the benefits that the Recursive InterNetwork Architecture (RINA) can bring into commercial DCNs. To this goal, we propose rule-based topological routing and forwarding policies tailored to the characteristics of publicly available Google's and Facebook's DCNs. These policies can be programmed in a RINA-enabled environment, enabling fast forwarding decisions in most scenarios with merely neighboring node information. Upon DCN failures, invalid forwarding rules are overwritten by exceptions. Numerical results show that the scalability of our proposal depends on the number of concurrent failures in the DCN rather than its size (e.g., number of nodes/links), dramatically reducing the total amount of routing and forwarding information to be stored at nodes. Furthermore, as routing information is only disseminated upon failures across the DCN, the associated communication cost of our proposals largely outperforms that of the traditional IP-based solutions.

Status: Accepted

Article no. 17

Conference: IEEE Cloudnet 2016[16]

Title: Assuring QoS Guarantees for Heterogeneous Services in RINA Networks with ΔQ

Submission: May 2016

Abstract: With the increasing usage of cloud computing and dependence on a diverse set of distributed applications, users are reliant on consistent

[16] http://cloudnet2016.ieee-cloudnet.org

outcomes from a shared infrastructure. This drives the need for absolute QoS guarantees for heterogeneous communication requirements over shared networks. The Recursive Inter-Network Architecture (RINA) is a clean-slate programmable network model that provides full QoS support for current and new service requirements. In this work, we focus on evaluating the QoS provided by such polyservice RINA networks. This exploits the concept of ΔQ, providing a QoS framework able to guarantee predictable outcomes to heterogeneous data flows. Indeed, strict limits on the maximum experienced losses and delays (ΔQ) can be enforced through the smart utilization of traffic policing and shaping strategies, together with an analytical pre-dimensioning of the buffer sizes. Our targeted scenario is a backbone network that prioritizes communications among geographically-distributed datacentres using resources shared with best-effort background traffic. Results obtained with the RINASim simulation software show that a ΔQ-enabled RINA network can yield the desired absolute QoS guarantees to the assured traffic classes without negatively impacting the best effort traffic, as it is the case with current MPLS-based VPN solutions.

Status: Rejected

Article no. 18

Conference: IEEE Cloudnet 2016[17]

Title: On Load Management in Service Oriented Networks

Submission: May 2016

Abstract: In traditional Service-Oriented Architecture (SOA), dedicated intermediate nodes called load balancers are usually deployed in data centers in order to balance the load among multiple instances of application services and to optimize the resource utilization. But on the other hand, the addition of these nodes increases the installation and operational cost of data centers. These load balancers distribute incoming flows to multiple outgoing ports usually by hashing them. The selection of outgoing ports is either on a round robin basis or based on some other heuristics e.g. queue length, feedback from neighbors etc. Such load balancing approaches do not consider getting live feedback from

[17] http://cloudnet2016.ieee-cloudnet.org

the service end and therefore are not able to dynamically change the amount of allocated resources. Moreover, in a Microservices-Architecture (MsA), the load on microservices is usually not considered by the front-end application while sending them the jobs. Although the lifetime of flows toward microservices is short, however, considering their actual load while allocating them a job may result in more optimal resource utilization. In this paper, a distributed load management scheme is proposed for service oriented networks based on the current Internet architecture. In this scheme, lightweight interconnected management agents are used to decide the availability for a particular service instance and help in optimal distribution of the flows. The proposed scheme can also be applied in other emerging internetworking architectures such as RINA.

Status: Accepted

Article no. 19

Conference: Asia-Pacific Conference on Communications 2016[18]

Title: Exploring the flexibility of network access control in RINA

Submission: May 2016

Abstract: RINA is a promising network architecture that conceives networking as distributed Inter Process Communication (IPC). In RINA there is a single type of programmable layer (the DIF ``Distributed IPC Facility''), that repeats as many times as needed by the network designer. Each layer is composed of only two programmable protocols: one performs data transfer and data transfer control functions, while the other carries out layer management functions. Multiple policies can be plugged to both protocols at each layer to adapt them to operational requirements. In this paper we explore the benefits of the RINA architecture on the access control area with respect to the IP protocol suite, specially regarding layer management functions. By designing and implementing a capability-based access control policy we show that RINA allows for finer granularity in access control decisions than current approaches. Moreover, the policy can be applied to any layer in the network, maximizing the re-use of specifications and implementations.

Status: Accepted

[18] http://apcc2016.org/

Article no. 20

Conference: IEEE LCN 2016[19]

Title: Even Lower Latency, Even Better Fairness: Logistic Growth Congestion Control in Datacenters

Submission: May 2016

Abstract: Datacenter transport has attracted much recent interest, however, most proposed improvements require changing the datacenter fabric, which hinders their applicability and deployability over commodity hardware. In this paper, we present a novel congestion controller, Logistic Growth Control (LGC), for datacenters which does not require changes to the datacenter fabric. LGC uses a similar ECN marking as in DCTCP, but adapts to congestion using the logistic growth function. This function has been proven to have nice characteristics including stability, convergence, fairness, and scalability, which are very appealing for congestion control. As a result, our LGC mechanism operates in the datacenter network in a more stable and fair manner, leading to less queuing and latency. LGC also behaves better than DCTCP, and it converges to the fair share of the bottleneck link capacity irrespective of the Round-Trip-Time (RTT). We discuss the stability and fairness of LGC using a fluid model, and show its performance improvement with simulations.

Status: Accepted

Article no. 21

Conference: European Workshop on Performance Engineering (EPEW 2016)[20]

Title: Feedback in Recursive Congestion Control

Submission: June 2016

Abstract: In recursive network architectures such as RINA or RNA,it is natural for multiple layers to carry out congestion control. These layers can be stacked in arbitrary ways and provide more ways to use feedback than before (which of the many controllers along an end-to-end path should be

[19] http://www.ieeelcn.org/
[20] http://www.epew2016.unifi.it/

notified?). This in turn raises concerns regarding stability and performance of such a system of interact- ing congestion control mechanisms. In this paper, we report on a first analysis of feedback methods in recursive networks that we carried out using a fluid model with a packet queue approximation. We find that the strict pushback feedback based on queue size can have stability issues, but robust control can be achieved when each congestion controller receives feedback from all sources of congestion within and below its layer.

Status: Accepted

Article no. 22

Conference: IEEE CCNC 2017[21]

Title: Hierarchical Small World Overlay for Efficient Forwarding in Volunteer Clouds

Submission: July 2016

Abstract: Volunteer clouds is a new paradigm of cloud computing where volunteer resources, i.e. user machines are used instead of (or in addition to) dedicated resources, i.e. data centers. Although volunteer clouds offer potential benefits in terms of energy and cost saving as well as elasticity, the volatility and the scalability of the volunteer resources are still open challenges that need to be studied. In this paper, we focus on optimizing the forwarding process and managing the connectivity in a scalable and dynamic fashion in volunteer clouds. We show that volunteer clouds could be modelled by a small-world structure, characterized by short average path lengths among nodes, and strong local clustering, which implies small latency between nodes and therefore robust forwarding in the cloud. First, we propose to build a hierarchical small world overlay network supporting scalability and dynamicity constraints of volunteer clouds. Second, we explore the benefits of the use of the Recursive InterNetwork Architecture (RINA) as a networking solution. The advantages that RINA bring comparing to the IP protocol is its recursiveness and its layer management functions. RINA is based on a ”divide and conquer” strategy enabling scalability over large networks. On the other hand, in RINA there is a common layer management protocol that could be leveraged to design

[21] http://ccnc2017.ieee-ccnc.org/

a flexible and dynamic forwarding management layer to maintain our hierarchical small world overlay network. Finally, simulation experiments are provided to evaluate the performance of our proposal. The results show that our small world overlay network gives better performance by reducing the routing table size and the end-to-end latency compared to a random based overlay topology.

Status: Rejected, resubmitted to AINA 2017

Article no. 23

Conference: NetCloud 2016 Workshop[22]

Title: Assuring QoS Guarantees for Heterogeneous Services in RINA Networks with ΔQ

Submission: July 2016

Abstract: With the increasing usage of cloud computing and dependence on a diverse set of distributed applications, users are reliant on consistent outcomes from a shared infrastructure. This drives the need for improved QoS guarantees for heterogeneous communication requirements over shared networks. The Recursive Inter-Network Architecture (RINA) is a fundamental programmable network architecture that provides a consistent model for supporting QoS across multiple layers. In this work we evaluate the performance outcomes provided by such polyservice RINA networks in conjunction with per-layer ΔQ-based resource allocation policies. ΔQ provides a resource allocation model able to enforce strict statistical limits on the maximum experienced losses and delays through the smart utilization of traffic policing and shaping strategies, together with an analytical pre-dimensioning of buffer thresholds. Our target scenario is a backbone network that prioritizes communications among geographically distributed datacentres using resources shared with best-effort background traffic. Results obtained with the RINASim simulation software show that a ΔQ-enabled RINA network can yield the desired absolute QoS guarantees to the assured traffic classes without negatively impacting the rest, unlike current MPLS-based VPN solutions.

Status: Accepted

[22] http://2016cloudcom.ux.uis.no/conf/workshops/netcloud.html

Article no. 24

Conference: IEEE ICC 2017[23], Communications and Information Systems Security Symposium (CISS)

Title: Achieving Multi-Level Security in the Recursive Inter-Network Architecture

Submission: October 2016

Abstract: This paper proposes the architectural options for implementing Multi-Level Security (MLS) over a clean-slate networking architecture called Recursive Inter-Network Architecture (RINA). MLS refers to access control mechanisms for protecting classified data from subjects of different security statuses. RINA is a policy-based architecture where the MLS overall solution is dictated by policy in order to achieve more flexibility, greater security, and ease of configuration. The proposed MLS solution includes a number of options., which are policy-controlled, embedded functions that protect sharing of information between different networks/organizations and across security domains. The overall solution can also be used as an overlay RINA-based network service function over any networking technologies (e.g., Ethernet, IP). This is achieved with the support and realization of RINA's distributed inter-process communication facilities sitting on the top of these network technologies. In this paper, two main MLS architectures with a number of options are proposed for RINA. Their system-level implementations are described for realization using the Software Development Kit (SDK) developed in the FP7 European Commission projects. In this work, two main objectives have been achieved: 1) embedding the MLS security enablers in the network system architecture 2) verifying the applicability of the solution in a real networking environment.

Status: In review

Article no. 25

Conference: IEEE ICC 2017[24], Next Generation Networking and Internet (NGNI) Symposium

[23] http://icc2017.ieee-icc.org/
[24] http://icc2017.ieee-icc.org/

Title: Security Risk Analysis of the Recursive Inter-Network Architecture

Submission: October 2016

Abstract: In this paper, a recent security risk assessment methodology, is proposed to be systematically applied in a different context, i.e., to the network systems, specifically to an emerging recursive network architecture called RINA. It is used for identifying run-time threats, assessing the risks involved, and defining measures to mitigate them. The risk assessment is performed to: assess the impact and likelihood of occurrence of attacks relevant to the identified threats; evaluate the RINA design principles; and validate the built-in security enablers and the mitigation actions that are devised to combat such attacks. Resulting from this assessment, specific measures are proposed to further improve the cyber resiliency of the RINA network system, in securing its layers and components. These measures include enhancement to the existing security functions and the use of threat monitoring mechanisms.

Status: In review

Article no. 26

Conference: 3rd OMNeT++ Community Summit[25]

Title: Babel Routing Protocol for OMNeT++

Submission: August 2016

Abstract: Routing and switching capabilities of computer networks seem as the closed environment containing a limited set of deployed protocols, which nobody dares to change. The majority of wired network designs are stuck with OSPF (guaranteeing dynamic routing exchange on network layer) and RSTP (securing loop-free data-link layer topology). Recently, more use-case specific routing protocols, such as Babel, have appeared. These technologies claim to have better characteristic than current industry standards. Babel is a fresh contribution to the family of distance-vector routing protocols, which is gaining its momentum for small double-stack (IPv6 and IPv4) networks. This paper briefly describes Babel behavior and provides details on its implementation in OMNeT++ discrete event simulator.

[25] https://summit.omnetpp.org/2016/

Status: Accepted

Article no. 27

Journal: IEEE SDN Newsletter[26]

Title: Progressive Network Transformation with RINA

Submission: October 2016

Abstract: Networks nowadays are changing, evolving. The old-but-gold IP architecture is starting to show it's limitations in facing the problems arising nowadays, and the concept itself of Networking is moving towards software and virtualization definitions. RINA provides a possible solution that not only embrace such concepts by design, but allows to introduce such technology in a progressive way. There is no necessity to throw away everything done until now and reset the network, but instead the introduction of RINA can happen gradually and transparently. Complex software solutions already dispatched not only do not need to be immediately adapted to this new technology, but (while remaining untouched) they can gains benefits from the enhancements that recursive internetworking introduces.

Status: In review

2.3.2. Planned papers (short term, already in preparation)

Article no. 28

Journal: Elsevier Computer Networks[27] or similar

Title: Providing Improved QoS Guarantees for Heterogeneous Service in RINA Networks

Submission: November / December 2016

Abstract: With the increasing usage of networking services and cloud computing, users depend on a diverse set of distributed applications, each requiring specific and consistent outcomes from the shared infrastructures. This drives the need for improved QoS guarantees for heterogeneous communication requirements over shared networks. Typically, in order to

[26] http://sdn.ieee.org/newsletter
[27] http://www.journals.elsevier.com/computer-networks

provide some sort of QoS guarantees for heterogeneous communication, network managers have relied on the overprovisioning of resources, something not really cost-effective nor viable as the requirements of communication increases. In this work, we propose the use of the Recursive InterNetwork Architecture (RINA) model as a replacement for the current IP network, a programmable network architecture that provides a consistent model for supporting QoS across multiple layers. We evaluate the performance outcomes provided by different polyservice RINA networks in conjunction with per-layer ΔQ-based resource allocation policies in overbooked scenarios. The use of ΔQ policies allows of a resource allocation model capable of enforcing strict statistical limits on the maximum experienced losses and delays through the smart utilization of traffic policing and shaping strategies, in conjunction with an analytical pre-configuration of buffers. While ΔQ policies can be used at any layer, we focus on the data centre fabric, backbone network and Wi-Fi scenarios, being those two ones of the more restricted scenarios and with a great effect on the quality of end-to-end traffic. Results obtained with the RINASim simulation software and the RINA SDK show that a ΔQ-enabled RINA network can yield the desired QoS guarantees to the more assured traffic classes without negatively impacting the rest, unlike current MPLS-based VPN solutions.

Status: In preparation

Article no. 29

Journal: Elsevier Computer Networks[28] or similar

Title: Reducing Complexity with Programmable Forwarding and Routing in Large-Scale RINA-enabled Data Centres

Submission: November / December 2016

Abstract: Given the current expansion of cloud computing and the expected evolution of Internet of Things (IoT) and needs of future 5G network scenarios, larger pools of computational resources will be required soon and this implies the need for more efficient and scalable data centres, capable of provide those computational resources and storage capabilities in a cost-effective way. A quick look to today's commercial data centres

[28] http://www.journals.elsevier.com/computer-networks

shows that they tend to rely on small variations of well defined leaf-spine Data Centre Network (DCN) topologies that not only offer low latencies between any pair of nodes, but also high bisectional bandwidth and enhanced reliability against multiple concurrent failures. However, DCNs are typically restricted by the use of the IP model, thus suffering from its limitations in routing scalability, lack of service oriented QoS, etc. In this work, we study the benefits that the replacement of the current IP model with the Recursive InterNetwork Architecture (RINA) model can bring to commercial DCNs in terms of routing scalability. We quantitatively evaluate the benefits that RINA solutions bring with respect to those based on IP and also see how, with the use of RINA, new topological solutions can be enabled to improve even more the efficiency of the network. To this goal, we propose a rules-and-exceptions topological forwarding policy tailored to the characteristic of these networks. This policy enable fast forwarding decisions based in small rules in most scenarios with merely neighbouring node information, requiring only few exceptions to overwrite those rules upon DCN failures, those exceptions being computed either in a distributed or centralized way, profiting from the existing computational resources. Numerical results shows that the scalability of our proposal depends mainly on the number of concurrent failures in the DCN rather than its size (with the exception of direct neighbours information), reducing dramatically the total amount of forwarding and routing information required at nodes. Furthermore, as routing solutions already takes the errorless network graph as known, only failure related information needs to be disseminated, reducing greatly communication cost of our proposal, largely outperforming that of traditional IP-based solutions.

Status: In preparation

Article no. 30

Journal: To be discussed

Title: An Analysis of the Security Policies In the RINA Architecture

Submission: Q1 2017

Abstract: The idea of the paper is to deliver the whole picture of security related work in RINA. The objective of this paper is to show that RINA covers a comprehensive list of security aspects and defines and implements

policies for each of them: SDU protection, authentication and access control. In addition, this message can be further confirmed by adding a security analysis of these policies by identifying threats, impact of these threats and corresponding countermeasures. Thus, we first briefly recall where security is needed and how RINA is good for the design in general; then we describe each security policy and its main operations; and finaly we perform a security analysis. For this aim we consider the enrollment scenario within a DAF and list all the security threats of this scenario (e.g. for CBAC for instance: eavesdropping the token or profiles, token replay, etc) followed by the proposed countermeasures for these potential attacks.

Status: In preparation

2.4. Organisation of workshops

Workshops have been a key component of PRISTINE's dissemination strategy. The workshops planned in D7.3 had three main objectives: to disseminate the RINA theory, disseminate the project results and offer live demonstrations of the work carried out. Two PRISTINE workshops have been held after the ones reported in D7.3. The first one was held in Pisa in October 2015, while the second one was organized at the end of the project (October 2016).

2.4.1. Evolution and Revolution in the Internet: Software Defined Networks and new network architectures

The Pisa workshop was co-located with the PISA Internet festival [pisafest], an initiative open to the wide public with the purpose of disseminating knowledge related to the world. The festival took place from 8th - to 11th of October 2015. PRISTINE, Nextworks and the University of Pisa organized a 4-hour workshop in the context of the PISA Internet Festival 2015. The workshop discussed with invited experts from leading industries and researchers how Software Defined Networking, Network Function Virtualization and RINA can change and enhance the networks and the services for the Internet. The event was attended by an audience of about 50 people, composed of PhD students, researchers and industry professionals. The workshop featured the following talks:

- **The SDN/NFV puzzle and its missing pieces**. *Pedro A. Aranda (Telefonica)*

- **Load balancing with SDN/NFV**. *Gert Grammel (Juniper)*
- **PRISTINE Introduction**. *Miguel Ponce de Leon (WIT-TSSG)*
- **RINA Essentials**. *Eduard Grasa (Fundació i2CAT)*
- **Model-driven OpenFlow interoperability**. *Curt Beckmann (Brocade)*
- **NFV System – NFVI offering from HPE**. *Arnaldo Fornasiero (HP)*
- **The role of NRENs in SDN/NFV research**. *Mauro Campanella (GARR)*
- **Panel discussion on demand for new technologies, standardisation implications and priorities for the future**. *Moderated by Gino Carrozzo (Nextworks)*

Figure 4. PRISTINE's coordinator giving key RINA ideas during PISA Internet Festival

The more interesting feature of the workshop - what the audience enjoyed more - was the diversity in the presented approaches as well as the different backgrounds of the speakers. Strong points and limitations of SDN, Openflow and NFV were debated against the more wholistic and fundamental RINA approach - which also takes more time to develop. The panel precisely discussed about the industry demand for such kind of solutions, the need for open standards as well as the top priorities in research and standadisation.

2.4.2. PRISTINE Workshop at the SDN World Congress 2016

The PRISTINE third and final workshop was celebrated in conjunction with the SDN and OpenFlow World Congress 2016 held in The Hague,

Holland in October 2016. The culmination of 2 and half years research work on the PRISTINE project, was presented at the RINA Workshop which is an annually organised event, allowing researchers interested in the Recursive InterNetwork Architecture (RINA) to present their work and discuss advances relating to their research on RINA.

The PRISTINE project has been an intrinsic part in advancing the design and implementation of the innovative internals of the RINA clean-slate architecture. This includes the programmable functions for: supporting congestion control, providing protection/resilience through load balancing, and facilitating more efficient topological routing, and multi-layer management for handling configuration, performance and security.

This version of the workshop was targetted and attracted industrial communities (representatives of key initiatives, manufacturers, service providers) and allowed for the PRISTINE consortium partners to be able to show how RINA is a new way of delivering network function virtualisation (NFV) providing clean:

- Layer 2 Agnostic Networking.
- Global layer 2 vLANs for Software Defined Data Centers (SDDCs), Cloud Providers and Network Service Providers.
- Application Specific Name Spaces for Billions of IDs.
- Inherent Application Security for Distributed Services.
- Isolated 'Network Slices' for End to End Services use that can really Guarantee QoS per slice.
- Pro-Active Congestion Control.

The team was excited about being able to present their work at the SDN World Congress an industry leading debating forum and showcase environment for the rapidly growing and massively influential, Software-Defined Networking and Network Functions Virtualisation industries. Now, with over 100 supporting partners and sponsors, and 1,500+ delegates, the SDN World Congress has established itself as the principal network innovation conference in Europe for the global telecommunications industry. The PRISTINE project was right there in the middle of it with a Stand (Booth 112 on the 1st Floor) and the workshop presentation.

Figure 5. PRISTINE's SDK leader delivering his speech during SDN World Congress

The agenda was especially crafted to give the audience the full breath of the RINA research carried out by PRISTINE, with each presentation ending with a demonstration.

Table 2. Workshop Agenda

Time	Name of Presentation and Presenter
15:40pm	**Chair's Opening Address**: Miguel Ponce de Leon, Chief Technologist, TSSG, Waterford Institute of Technology (logo required for workshop) (5 mins)
15:45pm	**RINA introduction**: Eduard Grasa, i2CAT. Industry oriented introduction to RINA. Given as a direct presentation. (20 mins)
16:05pm	**Slicing / SDN / Virtualisation and RINA**: Neil Davies, <PNSol>. Discussed the DIF as a native network slice, how its performance and security can be isolated, how each DIF can be customized via policies (10 mins). Showed demo of datacentre with VPNs (5 mins).
16:25pm	**Security and RINA**: Peter Thompson, <PNSol>. Discussed the isolation provided by the DIF, how DIFs can be secured via policies. Also discussed Key Management System: specification in RINA (10 mins). Showed the ISP security use case demo (5 mins).
16:45pm	**Naming and addressing / mobility**: Eduard Grasa, <i2CAT>. Discuss RINA inherent support for multi-homing, the advantages of having application names, the no need of special protocols to support mobility, etc. (10 mins) Showed the renumbering demo. (5 mins)
17:00pm	**Programmable congestion avoidance**: Peyman Teymoori <University of Oslo> Discussed RINA's inherent congestion control properties,

Time	Name of Presentation and Presenter
	flexibilities, and performance gains without the side effects of the proposals in the Internet. (10 mins)
17:15pm	**Interop / deployment**: Vincenzo Maffione <Nextworks>. Discussed RINA deployment strategies (shim DIFs - RINA as overlay, RINA as a substrate, application API, gateways). (10 mins) Showed the demo with the ssh/web server and TCP gateway. (5 mins)
17:30pm	**NFV support in RINA**: Diego Lopez <TID> and Kewin Rausch <Create-Net> (Kewin for demo). Discussed the advantages provided by RINA as an NFV and/or service chaining substrate (10 mins). Demoed NFV over RINA (5 mins).
17:45pm	**RINA Unplugged**: John Day, Neil, Eduard, Peter, Gino, Diego (15 minutes)
	Workshop Session was officially closed at 18:15pm.

The overall workshop worked a charm, with numerous questions being asked during each presentation session, and the RINA Unplugged session at the end proving a big hit. In fact one of the attendees asked a question and then proceeded to answer his own question correctly, which is a sure sign that the workshop session did something right.

A sample of companies attending the workshop session included:

- Canonical
- Google
- Level 3
- Huawei
- KPN
- EE
- CPlane Networks
- Symantec
- RAD COM

All the slides from the workshop are available for download from the SDN World Congress 2016 site[29]

[29] http://www.layer123.com/sdn-webcast-mle123-live/

2.5. Participation in target events

During the second reporting period of PRISTINE several events related to Future Internet and Networking have been attended, as planned in D7.2 and D7.3, in order to achieve visibility and dissemination of PRISTINE's work. The project has actively participated in and contributed to the Concertation activities organised at Future Internet Research and Experimentation (FIRE Conference and Workshops), Future Internet (FI Assembly) and ICT programme (ICT Conference) levels. The events, the results presented, the work carried out during the events, and any significant outcomes are described in the following sections.

2.5.1. HiPEAC CSW, Technological Challenges to IoT Security (November 2016)

Title A Programmable, Recursive, and Secure Network Architecture supporting diverse access and applications including IoT

Abstract It is widely recognised that 5G is not only about new radio/wireless technologies, but also network architecture revolutions accompanied by intelligent network functions and protocols. RINA (Recursive Inter-Network Architecture) is a clean-slate programmable networking approach based on Inter-Process Communication (IPC) paradigm. The heart of this networking structure is naturally formed and organised by blocks of containers called "Distributed Information Facilities - DIFs" where each block has programmable functions to be attributed to as they required. A DIF as an organizing structure (layer) provides IPC services and are configured under the same policies. RINA architecture includes built-in security enablers for combating run-time threats as the key step towards the security-by-design concept in order to avoid incremental updates and plug-ins. This talk provides the innovative internals of this clean-slate architecture and how it handles various networking/security and application scenarios and tackles the challenging IoT issues.

Person Hamid Asgari (TRT-UK)

2.5.2. SDN and OpenFlow World Congress 2016 (October 2016)

Title PRISTINE booth showing demos and other results

Abstract In addition to the PRISTINE workshop reported in the former section, PRISTINE results and demos were presented in a dedicated project booth during the five days of the conference.

Person Miguel Ponce de Leon (Waterford Institute of Technology), Neil Davies, Peter Thompson (Predictable Network Solutions), Kewin Rausch (CREATE-NET), Vincenzo Maffione, Gino Carrozzo (Nextworks), Anis Laouiti (Telecom SudParis), Eduard Grasa (Fundació i2CAT), John Day (Boston Unversity)

Notes The week was busy at the PRISTINE booth, were partners of the project were prepared to show the final results of PRISTINE - as well as some initial results of ARCFIRE - in the form of several demos and presentation material. During the three central days of the conference a considerable amount of people stopped by at the PRISTINE booth (12-15 each day), with about half staying for at least 5 minutes and about 25% requesting to see one of the demos (on datacentre network slicing, security, NFV support in RINA and renumbering). Booth attendees belong to companies such as Detecon Consulting, Symantec, Radcom, Swisscom, Huawei and Strategy Analytics. Perhaps the most remarkable fact was that most people listened with respect and interest when they were told PRISTINE was investigating an alternative to TCP/IP - two years ago the most usual reaction was a smile followed by a quick scape.

Figure 6. PRISTINE partners disseminating the project results at the SDN world congress

2.5.3. Third OMNeT++ Community Summit (September 2016)

Title Introducing OMNeT++-based Research Frameworks: RINASim

Abstract RINA is a clean-slate approach trying to address issues of nowadays Internet. Issues like routing scalability of the default-free zone, cumbersome multihoming and mobility, problematic traffic engineering and QoS support, which are caused by design problems of traditional TCP/IP stack. RINASim is the first and only full-fledged simulator of native RINA networks that is being used as educational and research tool in the frame of multiple projects. For more information, take a look at the project's Github repository.

Person Marcel Marek (Brno University of Technology)

Notes After a successful RINASim presentation at the 3rd OMNeT Community Summit, the OMNeT community decided that the RIMASim framework is not only interesting but also worthy of further dissemination. Hence, RINASim was accepted as the official OMNeT++ feature

project. Now the official RINASim page has moved into https://rinasim.omnetpp.org.

Figure 7. RINASim presentation at the 3rd OMNeT++ Community Summit

2.5.4. IEEE SDN Workshop on 5G and Mobile Edge Computing (June 2016)

Title RINA: Recursive InterNetwork Architecture, Last advances from the PRISTINE project

Abstract This talk discusses an introduction to RINA with its key advantages with a special focus on network management and service provider networks.

Person Sven van der Meer (Ericsson)

Notes Sven presented RINA and PRISTINE in two sessions: a 1 hour discussion session on building POCs (Proof of Concept) and another 2 hour session on participant contributions. The audience was receptive to the message that a new architecture alternative to TCP/IP would provide a better basis to construct systems that can deliver on the requirements from 5G and Mobile Edge Computing. Feedback was positive, with opportunities to discuss potential RINA PoCs in the near future.

2.5.5. RINA Tutorial at EUCNC 2016 (June 2016)

Title RINA: a future-proof approach towards re--#architecting the infocomms protocol stack supporting Cloud, IoT and beyond 5G requirements

Abstract The goal of the tutorial is to provide the audience with an introduction to the concepts, motivation and state of the art of the Recursive InterNetwork Architecture (RINA), a network architecture based on the InterProcess Communication paradigm as an alternative to the incumbent TCP/IP protocol suite. RINA is a minimalistic, programmable network architecture that provides the elements necessary to support distributed computer networking at scales ranging from LANs over exascale datecenters to WANs. As such, it is an ideal candidate to effectively support the requirements for future networking scenarios such as 5G, IoT or private custom clouds, while providing the flexibility of SDN and NFV in a natural way. The tutorial will motivate and introduce RINA, discuss congestion control and security in RINA networks comparing them to the current state of the art, and present two tools that can be used to experiment with RINA: an OMNeT simulator and a programmable C/C implementation for the Linux OS.

Person Dimitri Staessens (iMinds), Peyman Teymoori (University of Oslo), Miquel Tarzan, Leonardo Bergesio (i2CAT), Vladimir Vesely (Brno University of Technology), Vincenzo Maffione (Nextworks).

Notes The audience was low due (5-10 attendees during the session) to the high number of parallel workshops and tutorials taking place at the same time. However, there was an interesting and deep conversation about RINA with a representative from the European Commission.

Figure 8. RINA Tutorial at EUCNC 2016

2.5.6. TERENA Networking Conference 2016 (June 2016)

Title PRISTINE Network Manager and ioquake 3 demos

Abstract This demo features the PRISTINE Manager creating and configuring tenant DIFs (layers) in RINA-enabled data-center (DC) networks. Figure 1 depicts the different systems (boxes) and DIFs (layers) that will be used in the demo, except for the Network Manager and the management DIF (to avoid overcomplicating the picture). The left part of the figure shows the RINA-enabled DC network, which will be located at one of the PRISTINE partner's lab. The DC network (except for the tenant DIFs) will be already pre-configured before starting the demo. The Network Manager will also be executing in the DC. The right part of the figure describes the configuration at the TNC demo venue, where one computer configured as border router and 4 computers configured as hosts will be located. The venue DIF will have already been setup before the demo starts. A shim DIF over the public Internet will allow the RINA network at the TNC venue to communicate with the RINA-enabled DC

network.A tutorial on how to re-create the DCN experiment and configure it with the Manger is available here[30].

Person Eduard Grasa, Sergi Figuerola (Fundacio i2CAT), Dimitri Staessens, Sander Vrijders (iMinds)

Notes The demo was attended by around 10 people during the show at the demos room. Attendees asked to go step by step through all the demo lifecyle, walking through the steps of setting up the DC fabric DIF, the two VPN DIFs and starting the ioquake games running over RINA. The audience raised questions on the commonality of the layers, how RINA could be applied to an NREN environment and what interoperability strategy could be applied to deploy RINA for real.

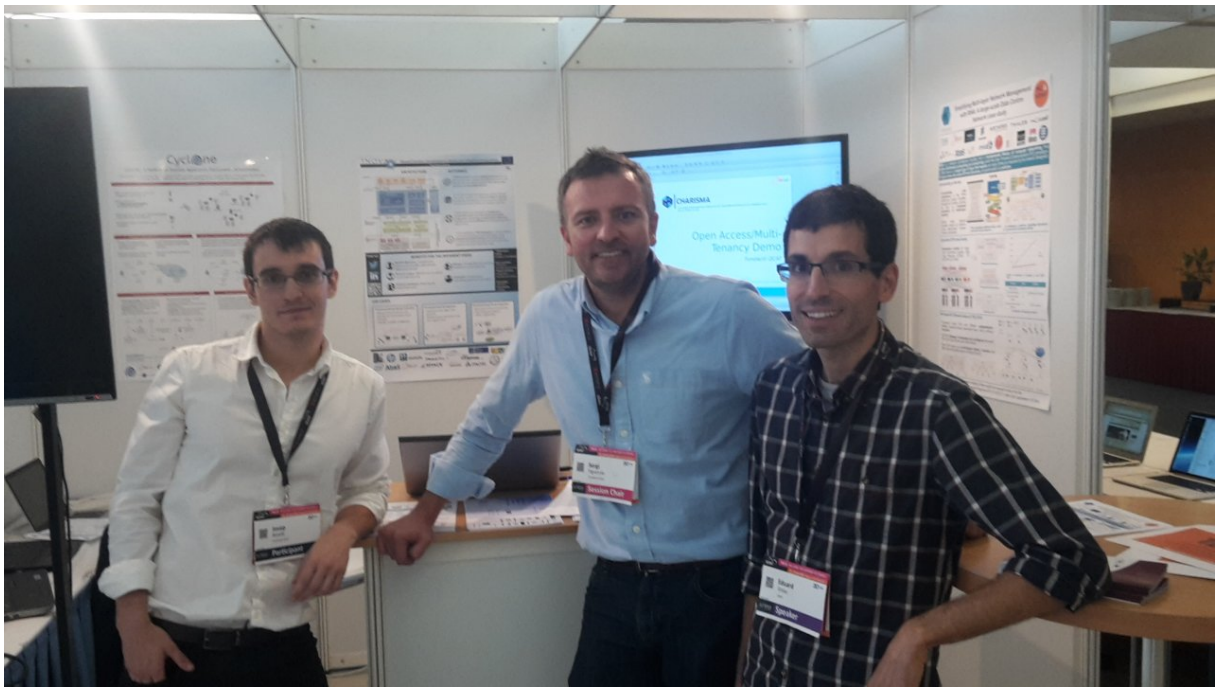

Figure 9. PRISTINE Network Manager and ioquake demo at the i2CAT booth at TNC 2016

2.5.7. Broadband World Forum 2015 (October 2015)

Title PRISTINE Network Intelligence

Abstract PRISTINE recently participated in an interactive discussion at the BroadBand World Forum 2015, in which ”Fit for Purpose Networks” along with the evolving nature of QoE based networks to enable the Future

[30] https://github.com/IRATI/stack/wiki/Tutorial-4:-Multi-tenant-DCN-TNC-2016

Internet was hotly discussed. The BroadBand World Forum is one of the world's largest telecoms, media & technology events. Pulling in over 7,800 senior executives from across the globe. During the Network Intelligence session, PRISTINE project co-ordinator Miguel Ponce de Leon, got a chance to discuss a long term communication network strategy that can support the developing digital economy with John Strand (Strand Consult) and Jon Aldington (GOETEC), along with Martin Geddes, a chief proponent of Fit for Purpose Networks.

Person Miguel Ponce de Leon (Waterford Institute of Technology)

Notes The session got a chance to highlight that more speed DOES NOT equal more value for broadband consumers and that in fact the global industry's obsession with speed is failing to deliver value to consumers. It is now becoming clear that the internet is at its limits, and that broadband services need the capability to meet their performance and availability needs. This in turn demands that operators look at new metrics and measures, since capacity alone fails to capture the needs for continuity, connectivity, and consistency. The overall pitch from PRISTINE is that with RINA an operator can make business promises on QoE that can be delivered ! The DIF API allows applications (and other layers) to request quality characteristics for their flows, such as delay, loss, and in-order-delivery of data to name a few. Then each DIF can allocate resources and schedule the packets belonging to different flows in order to comply with the promised flow characteristics. The usage of proper resource allocation and scheduling policies in each DIF is then key to deliver the quality promised to each flow. Quality attenuation is a framework to reason about the performance of statistically multiplexed packet networks, providing a scheduling model that allows to differentially allocate delay and loss between classes of competing flows. PRISTINE is investigating the Integration of quality attenuation as a resource allocation and scheduling framework for DIFs, and comparing them to the use of other scheduling policies such as weighted fair queueing.

2.5.8. GLIF technical meeting (September 2015)

Title RINA: Recursive InterNetwork Architecture, Last advances from the PRISTINE project

Abstract This talk discusses an introduction to RINA, the tools being developed by the PRISTINE project (simulator and SDK for the IRATI implementation) as well as some initial PRISTINE results.

Person Leonardo Bergesio (Fundació i2CAT)

Notes Remote talk given to about 40 network engineers attending the Technical Working Group session of the 15th Global Lambda Integrated Facility (GLIF) meeting.

2.5.9. Networld2020 Joint Expert Group and Vision Group Workshop (June 2015)

Title Applying RINA as a Clean-Slate Approach to Software Networks

Abstract Introducing RINA, as a formal approach for a new network architecture. Going beyond 5G will demand an underlying networking infrastructure able to support the dynamic allocation of resources, flexible function composition, elastic component placement and migration, and implicit security. While current approaches consider the adaptation of present mechanisms, such as overlays, clean-slate proposals can provide a rather better substrate. RINA has the potential to address 5G challenges through the application of new design patterns rooted on sound theoretical principles.

Person Diego Lopez (TID)

Notes Good chance to highlight the applicability of RINA to the new 5G infrastructures. General agreement that RINA principles would facilitate the advent of the next-generation infrastructures, though additional research was suggested on the question if this model fits the 5G small cells architectures.

2.6. Interaction with other ICT projects

During its last period, PRISTINE has pursued a collaboration with the FP7 NETIDE and H2020 ARCFIRE projects, as reported in the following paragraphs.

2.6.1. FP7 NETIDE[31] (2015)

About NETIDE. NetIDE aims to deliver a single point of entry to SDN development that supports the whole development lifecycle of network controller programs in a vendor-independent fashion. A controller- and gear-independent approach is used to support the development of Network Apps.

Collaboration. NetIDE comes with an Eclipse compatible plugin available in the Eclipse Market place, with Graphical Topology Editor, Code Editors and Simulation & Inspection tools. It is therefore an interesting tool to explore as a companion to the work being done in PRISTINE. In particular the Graphical Topology Editor is network agnostic and quite a generic network topology tool, which could be used in either specifying the PRISTINE testbed configuration of one of its use cases, or as a network topology graph as input towards RINASim (the RINA simulator developed by PRISTINE).

During a joint workshop that was held in September 2015 in the Intel offices in Ireland, NETIDE and PRISTINE participants discussed NeMo (a Network Modeling Language) which looks to a transaction based North Bound (NB) API which can allow applications to use intent-based policy, in order to create virtual networks comprised of nodes with policy-controlled flows. Its high level structuring and its ideas around reusable blocks may allow us to let it interact with RINA.

The team members concluded the workshop with a view that there are a number of open opportunities to explore and collaborate, such as:

- Configuration tool for PRISTINE use case deployment on the virtual wall
- Configuration for RINASim simulations

The NetIDE tool could possibly be used for a specific PRISTINE use case and joint researchers agreed that the PRISTINE D2.1 Network Service Provider use case, which trials the benefits of RINA technology by a Network Service Provider (NSP) and analyzes RINA as an essential component of the Network Functions Virtualization (NFV), would be the

[31] http://www.netide.eu/

best fit. This Network Service Provider use case covers Service Function Chaining (SFC). The figure below is an investigated of SFC, from the view point of the IETF, ONF, OPNFV, and ETSI.

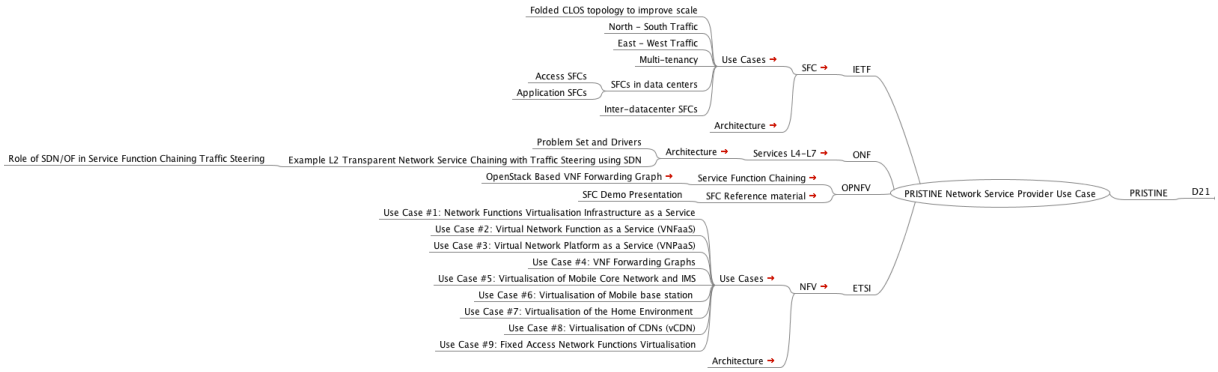

Figure 10. SFC from the view point of the IETF, ONF, OPNFV and ETSI

The most appropriate match was on the ETSI NFV Use Case #4: VNF Forwarding Graphs.

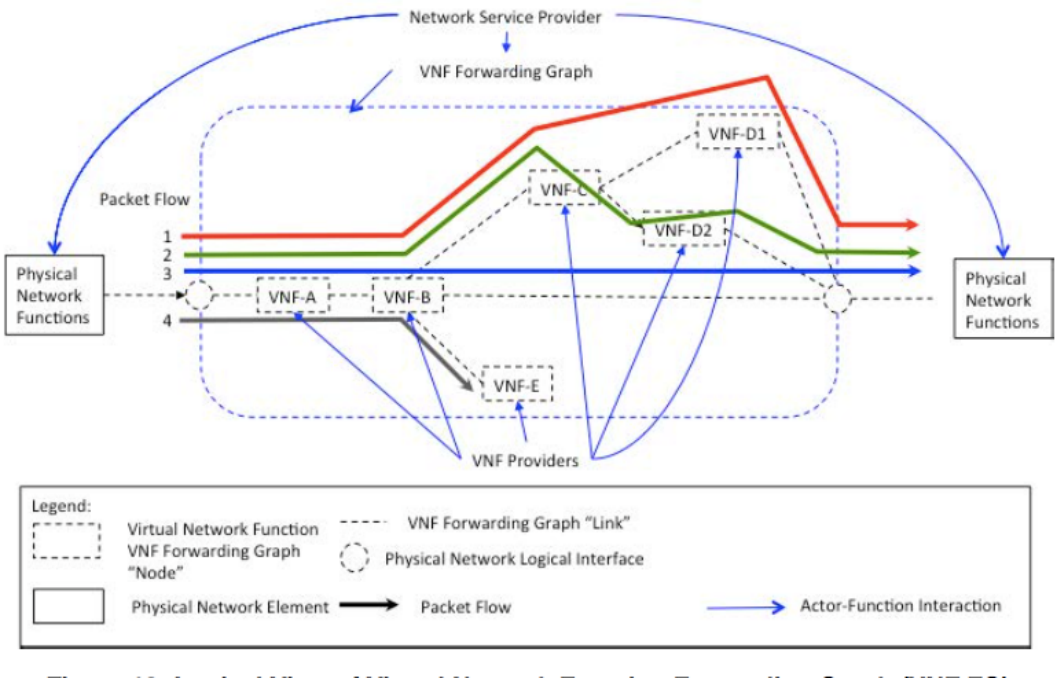

Figure 11. ETSI VNF Forwarding Graphs

In particular within the context of VNF Forwarding Graphs and Load Balancing, which is work being done in WP4 of PRISTINE.

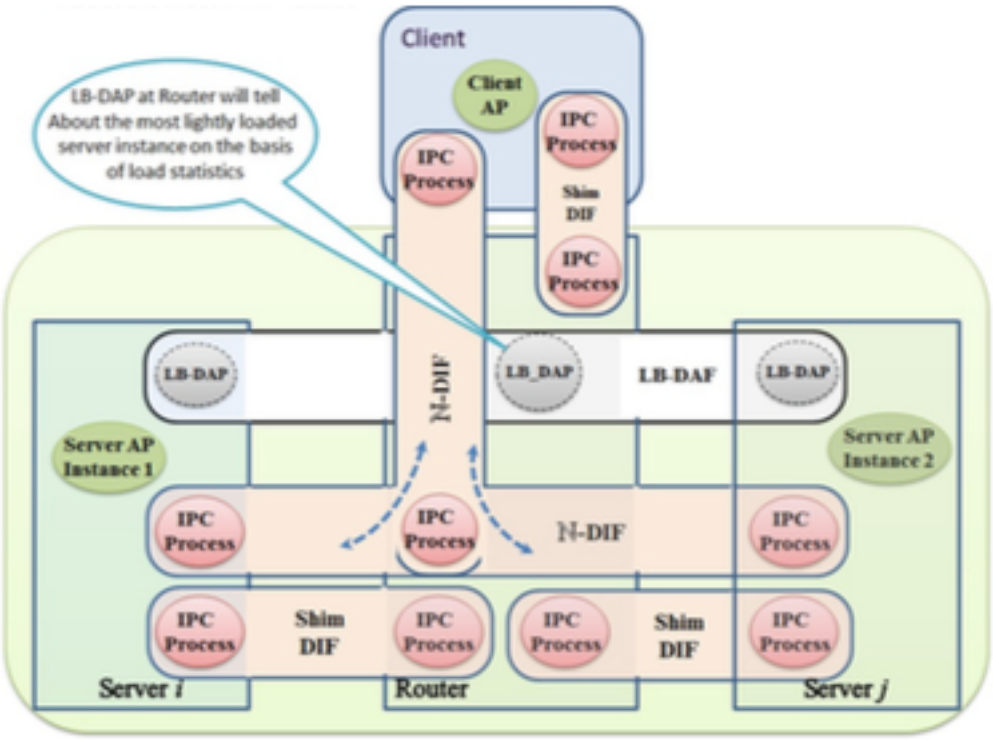

Figure 12. Load balancing in VNF Forwarding Graphs

On the PRISTINE side we looked at how NetIDE could be used to configure the RINA load balancing scenario and how to marry this into the RINASim environment.

NetIDE currently creates a mininet topology according to the GUI design topology. In order to create the mininet topology, the NetIDE engine uses some mininet topology customization scripts, and then translates the SDN application from source controller syntax to the destination controller syntax and executes that application. It opens the CLI interfaces for mininet nodes where one can run commands.

With this process in mind the PRISTINE researchers found that NetIDE could help in configuring RINA based network topology for RinaSIM. In order to make a working simulation scenario in RINASim, three configuration files need to be created. These are Network definition file with extension .NED, Initialization file with extension .INI and network configuration file in XML format. For NetIDE the mininet topology, it creates Python scripts while for RinaSIM, it should create the NED, XML and INI files.

The PRISTINE researchers provided this feedback to the NetIDE in early 2016 and await an update from the NetIDE consortium in regards to code changes with the NetIDE environment that would support this work.

2.6.2. H2020 ARCFIRE[32] (2016)

About ARCFIRE. The leitmotiv of ARCFIRE is to experimentally demonstrate the key benefits of RINA at large scale, leveraging on former EC investments in Future Internet testbeds (FIRE+), and in the development of the basic RINA technology (IRATI, PRISTINE). ARCFIRE's contribution will i) showcase the benefits and viability of RINA via large-scale experimental deployments; ii) quantify those benefits by comparing RINA with current Internet technologies using different Key Performance Indicators (KPIs) and iii) motivate the academic and industrial computer networking research communities to engage in RINA research, development and innovation activities. ARCFIRE will address the following specific objectives: (i) Compare the design of converged operator networks using RINA to state-of-the art operator network designs; (ii) Produce a robust RINA software suite; mature enough for large-scale deployments and long-lived experiments; (iii) Provide relevant experimental evidence of the RINA benefits for network operators, application developers and end-users; (iv) Raise the number of organisations involved in RINA research, development and innovation activities; (v) Enhance FIRE+ as a platform for large-scale experimentation with RINA.

Collaboration. ARCFIRE inherits the IRATI stack software enhanced with PRISTINE SDK, and is further advancing the software to get it ready for large scale experimentation. Moreover, the PRISTINE SDK is being used by ARCFIRE to develop new policies tailored to the mobile infrastructure. ARCFIRE is also following up PRISTINE standardisation activities in the context of ISO SC6 WG7 and ETSI NGP (Next Generation Protocols), as a track to initiate the standardisation procedure os some of the RINA core components and the RINA architecture as a whole. PRISTINE and ARCFIRE also collaborated to deliver a RINA workshop at the 2016 SDN World Congress in the Hague.

[32] http://ict-arcfire.eu

2.7. Feedback contribution to AT&T ECOMP

2.7.1. Background

In early 2014, AT&T made it a number 1 priority to support network transformation and launched its Domain 2.0 initiative (also known simply as D2). One of the key benefits stated for the Domain 2.0 program is the accelerated delivery of products and services, and calls for AT&T to virtualize more than 75 percent of its network using software-driven architecture by 2020.

This launch relates to the late 2013 release of a white paper by AT&T AT&T Vision Alignment Challenge Technology Survey, Domain 2.0 Vision White Paper, November 13, 2013[33] with a projection on what their business will look like in 2020 and beyond. The white paper offered some insights on adjustments that may be needed to AT&Ts architecture roadmap, and provided a vision on how it may plan to transform network technology, operations, infrastructure, software, and APIs in a way that would provide greater value to customers and application development partners. In the section on SDN Futures, RINA is referenced, and a note that "*AT&T also looks forward to advances through research that would make networking more directly applicable to developer needs with improved abstractions. Similarly, there's a growing school of thought that networking needs to become more sophisticated in the higher layers ...*" with a link the web site http://rina.tssg.org.

From the PRISTINE perspective one important element discussed in the white paper is the point that "*ECOMP*[34] *provides a Policy-driven operational management framework for security, performance and reliability/ resiliency utilizing a metadata-driven repeating pattern at each layer in the architecture. This approach dramatically improves reliability and resiliency as well as operational flexibility and speed*".

This one line expresses the key tenants of RINA and a maturing set of research work based on RINA projects such as IRATI[35], IRINA[36], PRISTINE[37] and ARCFIRE[38].

[33] https://www.att.com/Common/about_us/pdf/AT&T%20Domain%202.0%20Vision%20White%20Paper.pdf
[34] http://about.att.com/innovationblog/031716ecomp
[35] http://irati.eu/overview/

The indention of this document is to create an engagement with AT&T and to ask a few questions of the Domain 2.0 programme.

2.7.2. ECOMP Questions submitted to AT&T

Authors:

- Sven van der Meer (L.M. ERICSSON LIMITED)
- Miguel Ponce de Leon (Waterford Institute of Technology [TSSG])
- Eduard Grasa (i2CAT)

As members of the European FP7 ICT project PRISTINE (619305)[39], we would like to take this opportunity to contribute to the discussion on AT&T's D2.0 (2013)[40] vision and AT&T's ECOMP Architecture (2016)[41]. Our background is research and development of a new network architecture which is a potential replacement of TCP/IP in the small (i.e. within bounded scope as in data centers or virtualization environments) and in the large (i.e. in larger scale networks).

Our first question relates to the AT&T D2 document from 2013, which states in the section on SDN Futures that RINA is of potential interest with the note that "*AT&T also looks forward to advances through research that would make networking more directly applicable to developer needs with improved abstractions. Similarly, there's a growing school of thought that networking needs to become more sophisticated in the higher layers …*". The ECOMP whitepaper introduces Network Resource for connectivity but no longer discusses more sophisticated higher layer architectures such as RINA. So our first question towards the ECOMP team is:

> Does ECOMP still consider network architectures other than TCP/IP above base connectivity provided by for instance WiFi and Ethernet?

[36] http://irati.eu/welcome-to-irina-investigating-rina-in-the-nren-and-geant-environment/
[37] http://ict-pristine.eu/?page_id=48
[38] http://ict-arcfire.eu/index.php/about-arcfire/objectives/
[39] http://ict-pristine.eu/
[40] https://www.att.com/Common/about_us/pdf/AT&T%20Domain%202.0%20Vision%20White%20Paper.pdf
[41] http://about.att.com/content/dam/snrdocs/ecomp.pdf

With regard to the ECOMP whitepaper, the important aspect we are looking at is that "*ECOMP provides a Policy-driven operational management framework for security, performance and reliability/resiliency utilizing a metadata-driven repeating pattern at each layer in the architecture. This approach dramatically improves reliability and resiliency as well as operational flexibility and speed*".

This one line expresses the key tenants of RINA and a maturing set of research work based on RINA projects such as IRATI (2013-2015)[42], IRINA (2013-2015)[43], PRISTINE (2014-2016)[44] and ARCFIRE (2016-2018)[45].

RINA (via the above mentioned EU projects) has also created significant industrial consideration through the ETSI Next Generation Protocols ISG[46] and the IEEE SDN Newsletter article on SDN Architectural Limitations: Towards a Full Software Network Vision[47].

To our view, it looks like ECOMP assumes TCP/IP as the underlying network suite. Our second question now is:

> What would it mean for ECOMP to consider an alternative underlying network architecture and other network stacks (both other than TCP/IP) as potential facilitator of NFV and as an early requirement for IoT and 5G?

We strongly believe that RINA and the solutions created by the above mentioned EU projects can provide a significant contribution to ECOMP on a theoretic level (i.e. what would a new network architecture, based on a recursive pattern, add to the main ECOMP objectives) and on practical level (i.e. building an ECOMP/RINA testbed towards horizon 2020 with IoT and 5G use cases). We would be very interested to furthering a technical discussion on both aspects.

[42] http://irati.eu/overview/
[43] http://irati.eu/welcome-to-irina-investigating-rina-in-the-nren-and-geant-environment/
[44] http://ict-pristine.eu/?page_id=48
[45] http://ict-arcfire.eu/index.php/about-arcfire/objectives/
[46] http://www.etsi.org/technologies-clusters/technologies/next-generation-protocols
[47] http://sdn.ieee.org/newsletter/may-2016/sdn-architectural-limitations-towards-a-full-software-network-vision

This submission was made on May 26th 2016, as of the drafting of this report there is no solid response received from AT&T in regards to this submission.

2.8. PhD and MSc thesis

PhD and MSc thesis are important means for the dissemination of PRISTINE results in academia, with the potential to involve other academic institutions and the people working in them. The following PhD and MSc thesis have been activated or have been active during the reporting period:

Table 3. PhD and/or MSc thesis

Partner	Type	Duration	Topics
ATOS	MSc	Sept 2015 - Oct 2016	QoS aware multipath routing policies in Recursive InterNetwork Architecture (RINA)
CREATE-NET	MSc	Q4 2015 - Q3 2016	Performance isolation in data-centres networks
FIT-BUT	PhD	Sep. 2009 - Apr. 2016	Internet alternative architectures and routing paradigms
FIT-BUT	PhD	Sep. 2014 - estd. Q4 2017	Secure communication in RINA
iMinds	MSc	Sep 2014 - Sep 2015	Comparing RINA and TCP/IP for latency-constrained applications
iMinds	MSc	Sep 2015 - Sep 2016	Optimization of a BitTorrent file transfer protocol
iMinds	PhD	Sep. 2012 - estd. Q4 2017	Routing and resiliency in the Recursive InterNetwork Architecture
WIT-TSSG	PhD	Feb. 2015 - Oct. 2018	Energy Efficient Load Management in the Cloud
UPC	PhD	Sept. 2014 - estd. Q3 2017	Topological addressing, routing and resource allocation in the Recursive InterNetwork Architecture

2.9. Internal partner dissemination

PRISTINE partners have disseminated project results to other groups within their organisations. Internal dissemination has been achieved mainly through sharing of material, internal workshops and meetings.

The following table lists the internal dissemination activities carried out by PRISTINE partners so far.

Table 4. Internal dissemination

Partner	Date	Description
TRT-UK	27/09/2016	A Brown Bag presentation was given to TRT(UK) staff. This presentation introduced RINA and explained the security threat analysis as well as the work we did in PRISTINE in implementing Multi-Level Security (MLS) over the RINA as clean-slate networking architecture. The title of presentation was “Software Defined Secure Networking”.
iMinds	12/07/2016	Presentation of RINA and PRISTINE results at iMinds FUTURE INTERNET research strategy meeting.
TRT-UK	15/06/2016	It is widely recognised that 5G is not only about new radio/wireless technologies, but also network architecture revolutions accompanied by the design of intelligent network functions and protocols. Thales corporate hold a series of workshops. A presentation was given by TRT(UK) at JPAL 5G workshop (Les journees Palaiseau) in Paris to the attendees from Thales corporate. The title of presentation was “Recursion in Networking: A Vision for a Full Software Defined Secure Network” describing the RINA approach.
TID	06/06/2016	The RINA concepts and the PRISTINE results were introduced at TEFcon 2016 (http://blogthinkbig.com/tag/tefcon/), the global event for developers in the Telefonica group.
UiO	08/02/2016	Presentation on RINA and congestion control in a research group meeting.
ATOS	Q2 2015 / Q4 2016	Internal dissemination channels are ongoing in the company. These channels are in use to align the exploitation plan with the final results, validation and expertise got in the project. Atos has also included Pristine in the ARI (Atos Research and Innovation) booklet, which gathers Atos' R&D activities and which is distributed internally and also to our partners and clients.
UiO	30/11/2015	Presentation on RINA and PRISTINE in a research group meeting.
CREATE-NET	25/5/2015	The fundamental principles lying at the foundations of RINA have been presented to the students of the Wireless Networks course at the University of Trento

		(M.S. level, English speaking students). This was done as a 4 hour lecture where the general concept of recursion in network protocol was introduced, followed by the distinction of policy and mechanism in network management. Finally, RINA has been presented as the most promising architecture for future mobile applications where mobility and multi-homing shall play a key role.
FIT-BUT	21/10/14	Project was briefly presented to research and PhD students at the Third Annual Conference of IT4Innovations National Supercomputing Center, http://www.it4i.cz/. FIT-BUT is a member of IT4I consortium.
IMT-TSP	7/10/2014	Presentation of RINA at UCOOL Workshop. UCOOL is a STIC-AMSUD collaborative project between French and South American universities [imt-ucool]
WIT-TSSG	5/8/14	Presentation about RINA and PRISTINE for research group members attending a Pecha Kucha session [wit-tssg-pecha-kucha]
FIT-BUT	6/3/14	Presentation about RINA principles for research group members meeting [fit-meeting]
FIT-BUT	20/2/14	Presentation about RINA principles for BSc and MSc students of CCNP courses [fit-ccnp-courses]

2.10. External Advisory Board

PRISTINE has interacted with a number of organizations that have played the role of external advisors. These organizations have been presented the project's results and provided feedback that has influenced some of the research and development activities in the project. They have also participated in some of PRISTINE's dissemination and standardisation activities.

2.10.1. Active EAB members during the third period (M19-M30)

Boston University (USA)

Description of the Organization

Boston University (BU) —independent, coeducational, and non-sectarian —is an internationally recognized private institution of higher education and research. It is the third-largest independent institution of higher education in the United States. Through its fifteen Schools and Colleges,

thirteen of which offer advanced degrees, the University serves the academic and research needs of nearly 30,000 students and over 2,800 faculty. Government and Industrial funding of research conducted at Boston University has exceeded $250M in FY'05. Boston University's student body represents all fifty states and more than 135 foreign countries.

The Computer Science (CS) Department at Boston University was established in 1983 as part of the College (and Graduate School) of Arts and Sciences. Today, it consists of 19 full-time faculty members (in addition to 10 joint and affiliated faculty members) who teach and conduct research in diverse areas of theoretical, experimental and applied computer science. The Department's student body consists of over 200 undergraduate students and over 80 graduate students, of which over 50 students (all supported) are pursuing PhD degrees. Over the last decade, the Computer Science Department at Boston University has had significant growth in areas of networking, databases, computer vision, security and applied cryptography, operating systems and real-time systems.

BU's representative for the PRISTINE EAB is Mr. John Day. PRISTINE has benefited from BU's vision on the theoretical aspects of the RINA architecture, as well as of his more than 40 years of experience in the computer networking field.

Interaction with PRISTINE

Mr. John Day has also participated in the following events related to the dissemination and standardisation of RINA and PRISTINE results:

- PRISTINE Workshop[48] at the SDN and Openflow World Congress.
- Final panel at the NGP Forum[49] in the SDN and OpenFlow World Congress.

Interoute (UK)

Description of the Organization

Interoute owns the largest Next Generation Network covering the European Union. Interoute provides a single platform for Information

[48] http://www.layer123.com/sdn-agenda-day2/#Forum-8
[49] http://www.layer123.com/sdn-agenda-workshop/#Forum-11

Technology services, which we call Unified ICT. Connectivity, Communication and Computing services are integrated on a single infrastructure that reduces cost and optimises security, performance and efficiency. As a result, Interoute is key to Europe's digital supply chain, serving all the major incumbent operators as well as enabling for corporate customers more than €1 billion of e-Commerce transactions daily through our network. Consistently recognized as Europe's leading provider of bandwidth and transmission services, Interoute is increasingly distinguished for enabling Cloud Computing across the European footprint. Interoute is Europe's leading Cloud service provider; actively promoting our next generation secure Cloud solution to meet our customers business and community responsibilities. Our portfolio of advanced ICT services are designed to enable people to enjoy the benefits of the latest cloud technologies, promoting communications within companies and across the globe, while reducing carbon emissions that harm our planet.

Interoute's representative for the PRISTINE EAB is Mr. Adam Chappell, Chief Network Engineer. Mr. Chappell brings in his experience designing and operating the largest network in Europe, offering all sorts of services such as Internet access, several flavors of corporate VPNs and customized cloud services.

Interaction with PRISTINE

Mr. Adam Chappell has attended the first meeting of the ISG NGP in London (January 2016). During the meeting Mr. Chappell was very vocal explaining RINA's advantages and elaborating on why it is a future-proof bet from the perspective of a service provider such as Interoute.

Predictable Network Solutions (UK)

Description of the Organization

Predictable Network Solutions (PNSol) was founded in 2003 to provide consultancy on large and complex projects at the leading edge of feasibility, both technical and commercial. Coming from a strong scientific and engineering background we quickly found that the tools and techniques available were inadequate for the tasks we were being asked to perform. Our response was to construct both the mathematical basis and the practical tools that were needed to service our customers' needs. Since then

we have continued to work at this leading edge, spanning the issues of: performance; quality of experience; design and operational risks/hazards; and total cost of ownership. We have taken those tools and techniques and industrialised them.

We have worked with: major system integrators; network operators, both fixed and mobile; industry regulators; international research centres; network equipment manufacturers; and public sector bodies. Our telecommunications customers include small ISPs, medium sized national service providers and also large global carriers.

PNSol's representative for the PRISTINE EAB is Mr. Neil Davies, Chief Scientist and co-founder. Mr. Davies brings in more than 30 years of experience modeling, designing and building high-performance networked systems.

Interaction with PRISTINE

PNSol has joined the PRISTINE consortium as an official partner, taking part of the tasks previously assigned to Juniper.

TRIA Network Systems (US)

Description of the Organization

TRIA Network Systems is a start-up company founded by networking industry veterans that is creating networking products based on a new approach to defining and managing computer networks and new and improved ways for applications to use them. TRIA will introduce software products for use in embedded networks, private networks, in public and private clouds, and in the public Internet. TRIA's technology provides new capabilities that are difficult or impossible with current Internet technology and protocols.

TRIA's representative for the IRATI EAB is Mr. Steve Bunch. IRATI has benefited from the vast experience designing and implementing complex networking software that TRIA members have accumulated over the years.

Interaction with PRISTINE

Mr. Steve Bunch continued to be an active member of PRISTINE mailing lists, contributing to discussions about RINA implementation approaches,

the RIB and RIB Daemon libraries, the CDAP specification and RINA security aspects.

3. Standardisation

PRISTINE's standardisation strategy has been developed to achieve three main goals.

The first one is to contribute to the consolidation and enhancement of the experimental RINA specifications within the Pouzin Society (PSOC), the informal group that coordinates international RINA research and development activities. However, PSOC has been moved to a more formal approach in the editing process of specifications. PSOC has got an increase in its visibility by a newly-designed website.

The second one is to engage with established Standard Development Organizations (SDOs) such as ETSI or ISO in order to explore the possibilities for the standardisation of the RINA architecture at large. Representatives of the PRISTINE project have attended some of the ISG NGP meetings, discussing the contributions they can make. PRISTINE has also taken over the FP7 IRATI's efforts with regards to ISO as the best opportunity to standardise RINA with the goal of bringing RINA to the International Standards Organization (ISO) WG 7 "Network, transport and future network".

The final goal is to expose some of the particular solutions developed within the project to established SDOs. Examples of these contributions was the work on aggregate-based congestion control, which was presented at the IRTF Internet Congestion Control Research Group (ICCRG) or PRISTINE's view about Network Functions Virtualization (NFV), which is brought to ETSI's NFV ISG. The following sections provide details of the PRISTINE' standardisation plans.

3.1. Pouzin Society (PSOC)

PRISTINE is committed to improving existing RINA specifications and contribute new ones in the areas of congestion control, resource allocation, routing, authentication, access control, encryption and management. All these enhanced and new specifications have been contributed to the Pouzin Society (PSOC) [psoc]. PSOC was founded to coordinate contributions to the draft RINA reference model and specifications, making sure that new knowledge is incorporated and inconsistencies are fixed. PSOC - as a small group of well-aligned people with common

goals - has worked effectively on an informal basis. However, a growing number of contributors, resulting from the enhanced visibility created by FP7-funded projects IRATI [irati] and PRISTINE [pristine-homepage], BU's NSF grant, and the IRINA GEANT3 project [irina], has moved PSOC to transition to a more formal approach. A Memorandum of Understanding (MoU) defining PSOC protocols has to be signed by entities willing to become part of PSOC and gives access to the current RINA documentation and discussion channels. The specifications are stored in a github repository [psoc-github]. New and updated RINA specifications - in a variety of areas such as congestion control, resource allocation, routing, authentication, access control, encryption and management - resulting as public PRISTINE foreground are contributed to PSOC, in order to be taken into consideration for their adoption in future official releases.

During the second part of the project, PRISTINE tried to further organize the specification editing process. In order to do so, it assigned editors to all the RINA specifications, and specified a lightweight procedure to maintain, revise and approve changes to the specification documents. PRISTINE has also helped PSOC to increase its visibility by designing a new website that provides a one-stop shop for the RINA online presence; with links to RINA research projects, introductions to RINA, case studies, presentations, videos and other dissemination material (the new PSOC website work has already started during the first phase of the project).

3.2. Standardisation of RINA at large

3.2.1. ETSI Industry Specification Group on "Next Generation Protocols"

ETSI has created an Industry Specification Group to work on Next Generation Protocols (NGP ISG), looking at evolving communications and networking protocols to provide the scale, security, mobility and ease of deployment required for the connected society of the 21st century. The NGP ISG will identify the requirements for next generation protocols and network architectures, from all interested user and industry groups. The ISG provides a forum for interested parties to contribute by sharing research and results from trials and developments in such a way that a wider audience can be informed. PRISTINE and H2020 ARCFIRE - through i2CAT, Waterford Institute of Technology, Interoute and

Telefonica - are contributing to the NGP ISG by sharing the knowledge and results on researching and experimenting with RINA as an alternative to TCP/IP.

In particular, representatives of the PRISTINE project have attended the following ISG NGP meetings, discussing the following contributions.

NGP #1, London January 21st 2016

ETSI, the European Telecommunications Standards Institute, has launched a new Industry Specifications Group (ISG) to start work on Next-Generation Protocols (NGP) that go beyond what the current TCP/IP Protocol suite can provide. The ISG had its kick-off meeting in London during the third week of January. Amongst others, RINA was presented by PRISTINE and ARCFIRE representatives as an architectural framework that has the potential to solve the problems that this group wants to tackle. Eduard Grasa presented the contribution entitled "**Bad news, Good news, RINA Introduction**", discussing a brief analysis of the issues in the TCP/IP protocol suite and introduction to RINA and its implications.

PRISTINE members participating in the meeting: Interoute (External Advisory Board), Waterford Institute of Technology, Fundació i2CAT.

NGP #2, Sophia-Antipolis March 29th and 30th 2016

Representatives of PRISTINE attended the second ETSI NGP meeting that took place in Sophia-Antipolis (France). PRISTINE partners actively participated in this group, contributing to its goal to re-architect the current communications protocol stack. During the meeting two contributions with RINA background were presented and discussed:

- **Layers more or less**: A tutorial on how layers have been used in network and internetwork architectures to isolate different scopes, allocate resources in a divide-and-conquer fashion and allow networks to scale. RINA's recursive structure emerges as a generalization of the repeating layering pattern observed in many architectures.
- **How naming, addressing and routing are supposed to work**: A tutorial on the objects and names required for a complete computer network naming and addressing theory, and an analysis of the problems that happen when a subset of the object names/addresses are missing (such as in the current Internet).

PRISTINE members participating in the meeting: Waterford Institute of Technology, Fundació i2CAT.

NGP #3, Sophia-Antipolis July 26th and 27th 2016

During the 3rd meeting of ETSI's ISG NGP group, a **RINA tutorial** was presented as part of the discussion related to Work Item 3 (Next generation protocol architectures). The tutorial covered the basics of RINA (structure, DIF components, overview of data transfer and layer management), followed by a toy example of a RINA mobile network. The presentation triggered a lot of questions and a lively discussion with the audience.

PRISTINE members participating in the meeting: Fundació i2CAT.

In addition to standalone contributions and ISG NGP meeting participation, PRISTINE members John Day (External Advisory Board) and Eduard Grasa have contributed to the following documents released by the ISG NGP group.

- **White Paper** [isgngpwp]. The driving vision of ETSI NGP is a considerably more efficient and gradually evolving Internet that is far more attentive to service and traffic demands while enhancing efficiency and lowering the total cost of ownership for network operators. Technology requirements from different market segments, such as IoT, high and ultra-high definition video, and 5G networks and services, offer initial scenarios where the next generation of protocols should significantly simplify solutions. NGP assimilates a diverse set of requirements from these sectors/market segments as well as from a range of different network operations within the global ICT sector. Case studies in LTE-mobile networks, industry 4.0 and multiple Packet Data Network gateways in 4G are used as reference frameworks to highlight the benefits of state-of-the-art NGP solutions.
- **Work Item 1: Scenario definitions** [isgngpscen]. The present document introduces the NGP, ISG view on key issues with today's Internet Protocol (IP) suite when operated so as to interconnect these domains. In order to address the issues raised by the NGP, ISG, the present document introduces a reference set of scenarios that exemplify the current issues experienced in the operation of the existing IP suite for the NGP ISG to use in order to compare and contrast existing IP suite protocols with next generation IP suite protocol proposals. The document also lists example

use cases that should be considered as typical for each scenario, but it does not introduce any new use cases but instead references existing use case definitions from standardisation work in the next generation architecture and network standards market.

3.2.2. ISO

In D7.2, the International Standards Organization (ISO) WG 7 "Network, transport and future network" of SC 6 "Telecommunications and Information Exchange Between Systems" was identified as an interesting target for PRISTINE's standardisation efforts on two counts, timing and scope. The scope, the standardisation of an architecture that could cope with the requirements [iso29181] that WG7 is currently completing, suited perfectly the needs of PRISTINE and RINA.

In October 2014, the IRATI project sent representatives (iMinds, Nextworks, i2CAT) to the interim meeting in London. From the participation of that meeting emerged the possibility for the RINA community to start a New Project Proposal at ISO, should the community be interested in that. PRISTINE has taken over the efforts with regards to ISO as the best opportunity to standardise RINA.

PRISTINE attended in the SC6 plenary meeting in Ghent, May 25-29 2015, jointly organised by iMinds and NBN (Belgian standards organisation), attending the WG7 meeting and further discussing with the WG7 convenor opportunities to bring RINA to this working group, where a plan to initiate a New Project Proposal was drafted. Belgium (with iMinds as its representative to SC6) and Spain (with UPC as its representative and presiding over SC6 and i2CAT as SC6 secretary) initiated 2 NP ballots in November 2015, which were finalized after the SC6 Plenary meeting in Xi'an in March 2016. Both NP ballots found sufficient support, with 5 nominated experts for the architecture proposal and 6 nominated experts for the protocols proposal. Both NP proposals were rejected by the US national body (ANSI). A meeting was held in August 2016, where a resolution document was drafted and accepted by WG7. The next step is to submit working drafts to WG7 for both proposal for the next meeting early 2017.

3.3. Standardisation of specific contributions

3.3.1. IETF/IRTF

The Internet Engineering Task Force (IETF) works on standards for the Internet. These standards are based on compatibility to the current Internet, and ways of gradually improving it - very often in very small steps. This is the opposite of what PRISTINE intends to achieve with RINA, and therefore it is hard if not impossible for this project to contribute its outputs to the IETF. However, since several PRISTINE partners attend IETF meetings on a regular basis, it will be easy to keep track of current activities and align developments in the project accordingly wherever this makes sense, i.e. take inputs from the IETF. Again, given the "baby step" nature of IETF developments, this will not always make sense, but there are exceptions. For example, Transport Services (TAPS), a new IETF Working Group that was created due to the effort of a PRISTINE partner, will define services that should be exposed to applications rather than transport protocols. It would make sense for RINA to directly exhibit a similar set of services rather than trying to map stream (TCP) vs. datagram (UDP) socket-based applications onto the RINA service model.

The Internet Research Task Force (IRTF) is more forward-looking and research-oriented than the IETF. Similar to the IETF's Working Groups, it is organised into Research Groups (RGs). The diversity of the topics that RGs focus on is broad, ranging from the somewhat close-to-today's-network Internet Congestion Control RG (ICCRG) and Network Management RG (NMRG) to more drastic departures from today's common architectures such as Delay-Tolerant and Information-Centric Networking. It is therefore quite possible to contribute research results that PRISTINE has achieved in the context of RINA to some of these groups — e.g. congestion control results could be contributed to the ICCRG and network management results could be contributed to the NMRG. However, more visibility is achieved by the creation of a dedicated research group, and this possibility was therefore investigated.

In the IRTF research group, Internet Congestion Control (ICCRG), during IETF95 in Buenos Aires, we presented work on congestion control in recursive network architectures, highlighting the stability of chained and stacked congestion controllers in RINA, an overview of congestion signals and how they influence performance and a possible stable scalable new

type(s) of congestion control. The presentation was very well received, leading to discussions and even making someone join the mailing list of the Pouzin Society out of interest of industrial exploitation of RINA, and one of the audience mentioned that the work presented here is not just necessary for RINA but has wider applicability.

PRISTINE has contacted the IRTF chair and learned the following regarding RG establishment:

- RGs are measured by activity. An RG needs people to be active on the mailing list and attend the meetings. Attending meetings normally requires some interest in the IETF, as IRTF RGs often meet at IETF meetings.
- Establishment happens during a 1-year phase, where a mailing list and meeting space at IETF meetings will be given to the organisers, and the activity level will be monitored. If, after this year, there is clearly enough activity, an RG will be created.

This option was internally discussed in PRISTINE. Options on the table included establishing a dedicated RINA-RG - which would probably not attract enough attention - and a more general "new architectures" RG - which would mean a lot of PRISTINE resources wasted for an activity that is only partially related to RINA. It was discussed to try nevertheless, if only for the benefit of the impact/visibility of initial activities, but then it seemed that it does not make sense to start an endeavor that we already expect to fail from the outset. There are examples of rather similar groups that have failed in the past, e.g. the Virtual Networks RG (VNRG), which essentially consisted of delegates from various research projects presenting their own work that did not fit together with any other work. Eventually, the VNRG had to close down.

Beyond these contacts, it is worth noting that the IRTF has recently launched a group on Network Functions Virtualization (NFVRG). The areas of interests of this NFVRG are well aligned with the PRISTINE goals in the NFV use case, so a report of the findings of this use case would contribute to the build awareness about the RINA applicability to complex problems like VNF (Virtualized Network Function) internal and external orchestration, and to a cross-validation of potential further contribution to the ETSI NFV ISG.

In conclusion, PRISTINE will make sure to stay up-to-date on developments in the IETF to get inputs, and contribute some of its outputs to subtopic-specific Research Groups in the IRTF.

3.4. Summary

In addition to the aforementioned initiatives towards SDOs, some PRISTINE partners have specific long-term presence in standardization which turns into potential benefits for defining a concrete project standardization strategy.

3.4.1. UiO

UiO key person Michael Welzl has chaired the IRTF Internet Congestion Control (ICCRG) Research Group. This has facilitated having an overview of current congestion control developments, and helps planning contributions to future ICCRG meetings. UiO mainly works on aggregate congestion control and resource allocation. The results from evaluating aggregate congestion control have been presented in ICCRG during IETF95 in Buenos Aires, and the presentation was received very well. The future plan at UiO is indeed participating and presenting further under-development congestion control activities of RINA at future IETF meetings.

3.4.2. WIT-TSSG

WIT-TSSG have been active participants in the ETSI NGP ISG activities for PRISTINE in 2016, but of note we are also members of the Telecommunications Management Forum (TMForum) for the past 8 years and have had many inputs towards the Information Framework as standardised by the TM Forum. WIT-TSSG continue to explore the new blueprint being devised within the TM Forum which is looking at end-to-end management with Zero-touch Orchestration, Operations and Management, as such called the TMForum ZOOM project [zoom-project]. WIT-TSSG will be investigating whether the PRISTINE' DMS can be applied to the TMForum ZOOM project. This also has a link to the IETF Simplified Use of Policy Abstractions (SUPA) [supa] activities and while WIT-TSSG are not actively engaged in this IETF work group we shall endeavour to explore the possible linkages between the SUPA info and data models and the PRISTINE RIB.

3.4.3. i2CAT, NXW, iMinds

i2CAT and iMinds (now IMEC) initiated standardisation, delegating experts to their respective national bodies, in the ISO SC6 Working Group 7 on Future Networks with 2 NPs (New Proposals), one on Architecture and one on Protocols, which were both accepted. iMinds, i2CAT and NXW will continue the standardisation effort as part of the ongoing ARCFIRE project.

i2CAT, TID and NXW are also interested in exploring the possibility to setup a new technology oriented pre-standardisation group within ETSI about RINA (ETSI NGP).

3.4.4. TID

TID is mostly interested in contributing PRISTINE' results related to the NFV use case. TID aims at proposing seamless VNF and service construction to ETSI-NFV. TID also aims at supporting the possibility to setup a new technology oriented pre-standardisation group within ETSI about RINA.

4. Exploitation

One of the main goals of PRISTINE has been to bring RINA closer to real world deployment, by advancing the state of the art of the RINA specification and developing a prototype that is more tailored towards to real life industry use cases than what is currently available.

Though RINA as long-term commercial exploitation potential, also linked to a growing interest in clean-slate Internet architectures beyond the current approaches used in 5G and SDN/NFV, PRISTINE has contributed to further mature RINA solutions and stacks, working on robust prototypes which have the potential to heavily impact on commercial RINA products.

Therefore PRISTINE's exploitation strategy is not focused on immediate commercialization of project results, as the market is not yet there. Instead, PRISTINE will be exploited to help bridge the RINA technology and market gap, helping to foster future products as the larger RINA roadmap matures.

To ease this process of capitalization on PRISTINE foreground, the consortium has worked on the development of Business Model Canvas related to major PRISTINE results, to properly capture exploitable foreground items, together with channels and actions required to achieve them. The PRISTINE Business Model Canvas complement the individual exploitation plans by PRISTINE partners and provides each partner with a common reference analysis on RINA marketability surely useful to shorten time to market.

The remainder of this chapter deep dives into these aspetcs also covering ownership and IPR apsects where meaningful.

4.1. Business Model Development

In order to dig deeper on the timely commercialisation of results by Industry of the PRISTINE project, and to subsequently have a positive impact on both social and economic developments in Europe, the project team has had to choose a method to assist it in identifying and testing a variety of business model assumptions.

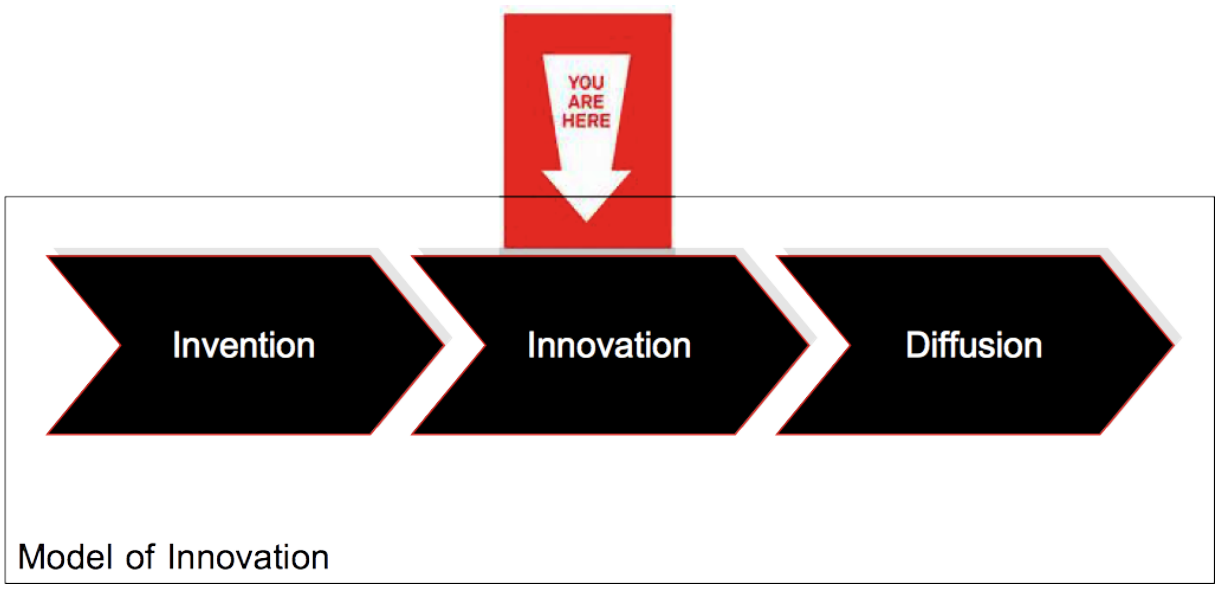

Figure 13. Model of Innovation

Through WP2 to WP6 the PRISTINE partners have created a working RINA stack, but the question now is to how to diffuse this innovation into the market and how would the project develop a business model around this innovation.

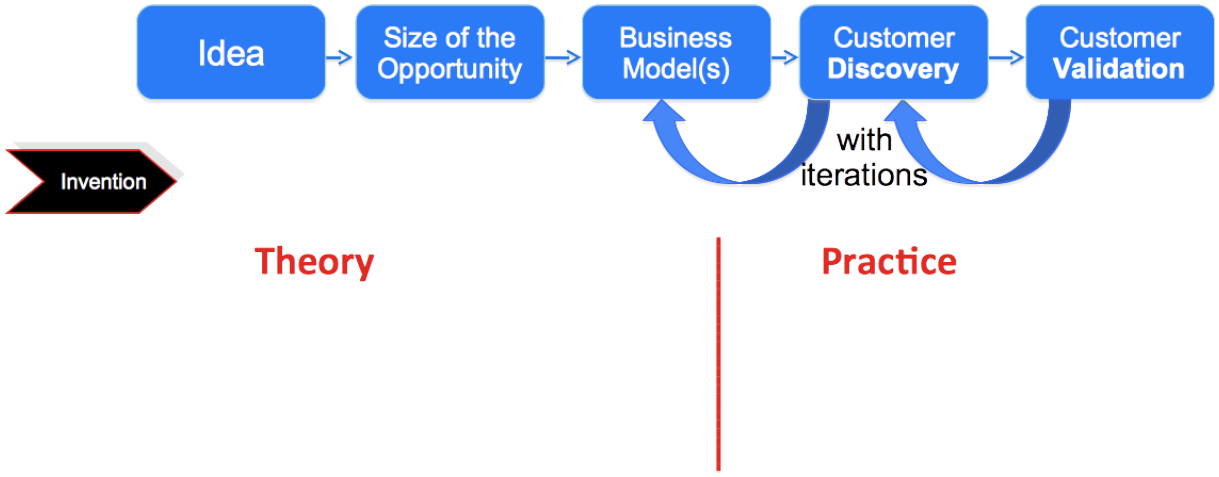

Figure 14. Bringing idea through to customer validation

The project set about capturing some ideas around the products and services that could go into making up the business model, with each idea investigated for the sizing of the market opportunity and some of our assertions on what the business model could be. This is the theory part, to make it real, the project went out to discovery customers and validate those customers over a few iterations.

The view was taken that the product/service could not and would not dictate the business model, as there may be a one to many relationship

between the product and the business model(s), with the appropriateness of business model(s) evolving over time.

The method chosen to help us long this path was the Business Model Canvas (BMC) [bmc], a process were all business assertions are hypothesis until validated. The Business Model Canvas facilitates the creation of a rudimentary plan of action to validate the hypothesis and we took a specific version of the Business Model Canvas called the Lean Business model canvas approach[50] which is a process that is more actionable and more a grounds-up tactical plan or blueprint for a RINA product.

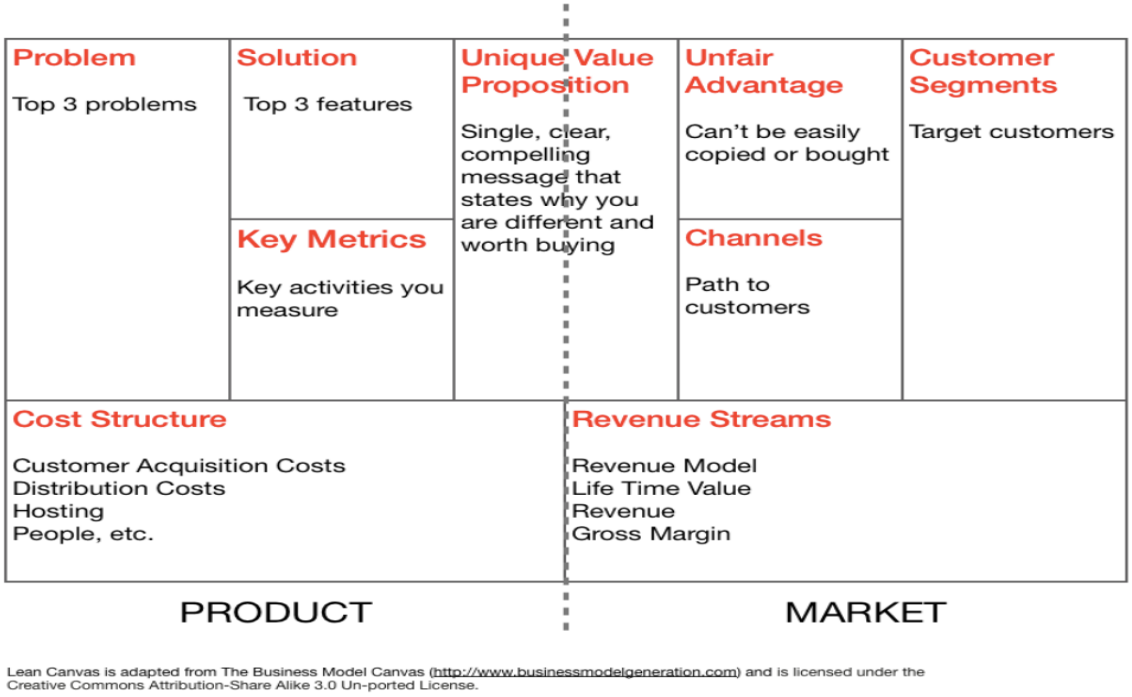

Figure 15. Lean Business Model Canvas

A brief explanation for each block:

- Problem: Briefly describe the top 3 problems you are addressing.
- Customer Segments: Who are the customers/users of this system? Can they be further segmented? For example, amateur photographers vs. pro photographers. If I have multiple target customers in mind, for example, graphic designers vs. lawyers, I will create a separate canvas for each. More than likely a lot of the other pieces like problem, solution, channels, etc. will be different too.

[50] http://leanstack.com/why-lean-canvas/

- Unique Value Proposition: What is the product's tagline or primary reason you are different and worth using?
- Solution: What is the minimum feature set (MVP) that demonstrates the UVP up above?
- Key Activity: Describe the key action users take that maps to revenue or retention? For example, if you are a blogging platform, posting a blog entry would be a key activity.
- Channels: List the FREE and PAID channels you can use to reach your customer.
- Cost Structure: List out all your fixed and variable costs.
- Revenue Streams: Identify your revenue model – subscription, ads, freemium, etc. and outline your back-of-the-envelope assumptions for life time value, gross margin, break-even point, etc.
- Unfair Advantage: This is usually the hardest one to complete. What are you doing that can not easily be copied or bought?

Of note there is an order in which to tackle each block namely to identify:

1. Problems;
2. Customer Segments;
3. Unique Value Proposition;
4. Solution;
5. Key Activity;
6. Channels;
7. Cost Structure;
8. Revenue Streams;
9. Unfair Advantage;

In order to capture our thoughts on the Lean Business Model, it was captured online Canvanizer website[51].

4.1.1. Customer Problems

In an effort to help identify problems in the space, we considered that there is a problem-customer pair. For each of the PRISTINE use cases distributed

[51] http://canvanizer.com

cloud, data-centre networking and network service provider, we looked at the markets value chain and then asked ourselves the question: "*When people need to get a job done, where would they hire a RINA product or service to do it for them*". During our internal workshop session for PRISTINE we identified the following problem-customer pairs.

Table 5. Table of Problem-Customer pairs as seen from WP2 perspective

Problems	Customer that has the problem
Need to check RINA functionality on its network design	Network designer, Network administrator
Want to develop their own RINA policy	Networking stack programmer, Developer
Wants to be educated on RINA Concepts	Developer, Lecturer
Develop security policies in RINA	Operator
Develop flow and congestion control policies in RINA	Networking software vendors
How to carry out RINA DIF and Policy testing	Multi-tenant DC providers, DC network architects

With a viewpoint on the types of customers that may be interested in the WP2 outputs we found a number of problems that the customers may have such as:

- Needing a way to check RINA functionality on their own network design in the closed and secure environment.
- Needing a way to develop their own RINA policy supporting its business requirements.
- Wanting a helping hand to educate its employees about RINA concepts.
- Wanting to develop authentication, key agreement, encryption and integrity verification policies for the RINA implementation.
- Wanting a modular RINA implementation in which they can load different plug-ins for flow and congestion control.
- Wanting to quickly setup a test environment to validate his implementation of certain RINA policies.

Table 6. Table of Problem-Customer pairs as seen from WP3 perspective

Problems	Customer that has the problem
Structural/Performance challenges in Split-TCP and Performance-Enhancing Proxies (PEPs)	Mobile Network operator, Satellite Network operator

Problems	Customer that has the problem
Latency in data centre	Data centre owners
Assured service outcomes while overbooking resources	Communication Service providers
Limited scalability of the TCP/IP protocol suite for routing/forwarding inside large-scale commercial datacentres	Data centre owners

When entering the viewpoint of customers that may be interested in the WP3 outputs, we unearthed the following problems that they may be having:

- Split-TCP and Performance-Enhancing Proxies (PEPs) that had fundamental structural and performance challenges.
- Unpredictable latency in the data centre network.
- How to maintain services to critical/essential/premium customers during such periods of demand exceeding supply.
- Routing and forwarding solutions in datacentre networks are typically based on TCP/IP, that do not scale well, resulting in large forwarding tables, routing burden and communication cost.

We also found that an overbooking of resources is an economic necessity to achieve sufficient users to amortise costs over. The same overbooking creates the potential for performance hazards which are triggered by both "normal" fluctuations in demand as well as peaks in demand due to external correlations. We also understood that information exchanged to populate routing tables and re-converge upon failures was causing latency in the data centre network.

Table 7. Table of Problem-Customer pairs as seen from WP4 perspective

Problems	Customer that has the problem
How to offer secure added-value services to tenants	Data-centre operators
How to have integrated key management	Enterprises
How to secure low-cost nodes	Network and Service Providers
How to do scalable charging for micro-services	Network and Service Providers
How to achieve secure data sharing in a multi-level security (MLS) environment	Data centre provider and Network and Service Providers

With a viewpoint on security and the types of customers that may be interested in the WP4 outputs we found a number of problems that customers may have which include:

- Data-centre operators would like to offer added-value services to their tenants. Managing the network infrastructure and inter-process connectivity could be such a service. However many tenants will be anxious to maintain control over their own credentials, which makes it difficult for the operator to manage authenticated connectivity between processes.
- Enterprises would like to manage the key material controlling inter-process connectivity using the same systems that they use for managing disk encryption keys, and message signing keys.
- Operators of systems of low-cost nodes (e.g. IoT) would like to make connections to them secure but cannot afford to include features that support this (reliable time-of-day clocks, TPMs etc)
- Intermediate organisations need to be able to give bounded access to third party services without revealing the identity of their customer.Disintermediation is a issue when access to systems can not be achieved without revealing the identity of the end user. Without intermediaries who can construct value propositions based on scale (e.g wholesalers / trusted intermediators to preserve anonymity for medical results).
- In particular, the ability to transfer data between networks at different sensitivity levels (e.g. a trusted and an untrusted network) in a way that can be securely controlled and dynamically reconfigured to rapidly respond to external events. For example, the ability to check imported data from untrusted networks for malicious activity, e.g. malware, or to inspect exported data from sensitive networks to prevent accidental or deliberate release of sensitive data.

Table 8. Table of Problem-Customer pairs as seen from WP5 perspective

Problems	Customer that has the problem
How to continuosly support scalability	Network and Service Providers, Data-centre operators
How to achieve modularity	Network and Service Providers,
How to automate network behaviour	Network and Service Providers, Data-centre operators

With a viewpoint on network management and the types of customers that may be interested in the WP5 outputs we found a number of problems that customers may have which include:

- Allowing managment of their network to scale, with the increase in connected devices
- How to enable modular (strategy based) management.
- How to reduce overhead by automating configuration and monitoring of DIFs when deployed.

4.1.2. Unique Value Proposition

The value proposition is an expression of where PRISTINE's offerings intersect with a customer's desire. It's the magic fit between what we have made on PRISTINE and why people would use it.

For *RINASim*, we have found that it allows basic validation and verification tests of native RINA networks, it offers a quick way on how to integrate and test brand new policies in the frame of the whole RINA stack. RINASim also employs a good GUI which easily visualizes the complex behaviour of RINA networks. This goes some way to addressing the Network designer and Network administrator problems highlighted in problem-customer pairs as seen from WP2.

The *PRISTINE SDK* enables policy developers to quickly develop the policies by just focusing on the APIs that are relevant to the functionalities that the customer wants to develop. All the other codebase can be safely ignored. The SDK also enables RINA network operators (e.g. multi-tenant DC providers, operators running NFV infrastructure in private DCs) to select a number of policies form the local catalogue installed in his system and configure them into the DIFs indicated by the customer. The SDK takes care of instantiating and plugin-in the policies into the adequate levels of the RINA stack.

Of note the *RINA Demonstrator* allows network designers to define a test scenario specifying the number of systems, connectivity between them, DIFs available at each system and policies available at each DIF. With this input the demonstrator executes a number of Virtual Machines connected as the user specified, instantiates the DIFs designed by the customer and

executes the enrollments as required. The operator just needs to focus on testing their policy, not in setting up complex test involving a few tens of machines.

As can be seen through the project in RINA, recursion arises from the ability to arbitrarily arrange structurally-equivalent DIFs. This allows each DIF to detect and manage the congestion for its resources, push back to higher layer DIFs when resources are overloaded. Moreover, improvements that have been done to TCP such as Split-TCP on the internet “naturally appear” with RINA without their side effects.RINA also aggregates flows at lower layers, leading to less competition among flows and increased performance, this is a clear unique value to RINA.

We also noted that a combination of the QTAMux (that can ensure bounded delay and loss on short - ballistic - timescales) and congestion control system that can signal the need to decrease demand over elastic timescales can assure services despite overbooking, solving one of the main problems outlined by customers in the WP3 perspective. We also find that the PRISTINE solution to topological routing and forwarding policies that make use of the DCN topology knowledge to forward packets to the closest neighboring device to their destination is a unique value proposition that cannot be replicated with systems build on TCP/IP. In the non-failure scenario, this approach only requires the storage of forwarding information per adjacent neighbour (compared to traditional forwarding tables, which may contain up to one entry per network node). Upon failures, the storage of merely few exceptions are enough to override invalid primary rules due to such failures.

On the security side the PRISTINE key management architecture makes it possible for the DC operator to initiate connections between processes (including those belonging to different tenants) without having access to or control over the tenant’s key material. The key management architecture also makes it possible for the key material to be managed externally by the enterprise via KMIP.

The capability access control gives the ability to have a secure token that provides transferable authentication/access control where the nature of the access control is embedded in the token itself. This permits, for example, a service wholesaler to give to its clients the ability to "spend" (to a limit) with another service (e.g. access to DAF or DIF while roaming) while not

revealing the end user identity (reduces potential for unauthorised identity capture).

Another use could be with sensitive personal information (e.g. medical test results) where access to the results themselves could be embedded within a capability which is passed, via a trusted intermediary, to the end user who can then access them preserving their anonymity.

With a considered eye on IoT, the PRISTINE key management architecture allows key management functions to be proxied to a central key manager on a trusted node. Compromising the low-cost node will not reveal key material stored on the trusted node.

On the network management side, with RINA in play, we start to see a smart, scalable and secure network, allowing the network service provider to truly choose features for the ideal network management solution and make the network fit for purpose, allowing for the automation of network operation, allowing the NSP to focus on the services/applications on top of it.

4.1.3. Business Model Canvas for WP2, WP3, WP4 and WP5

The detailed elaboration of the Business Model canvas for WP2, WP3, WP4 and WP5 results is reported below.

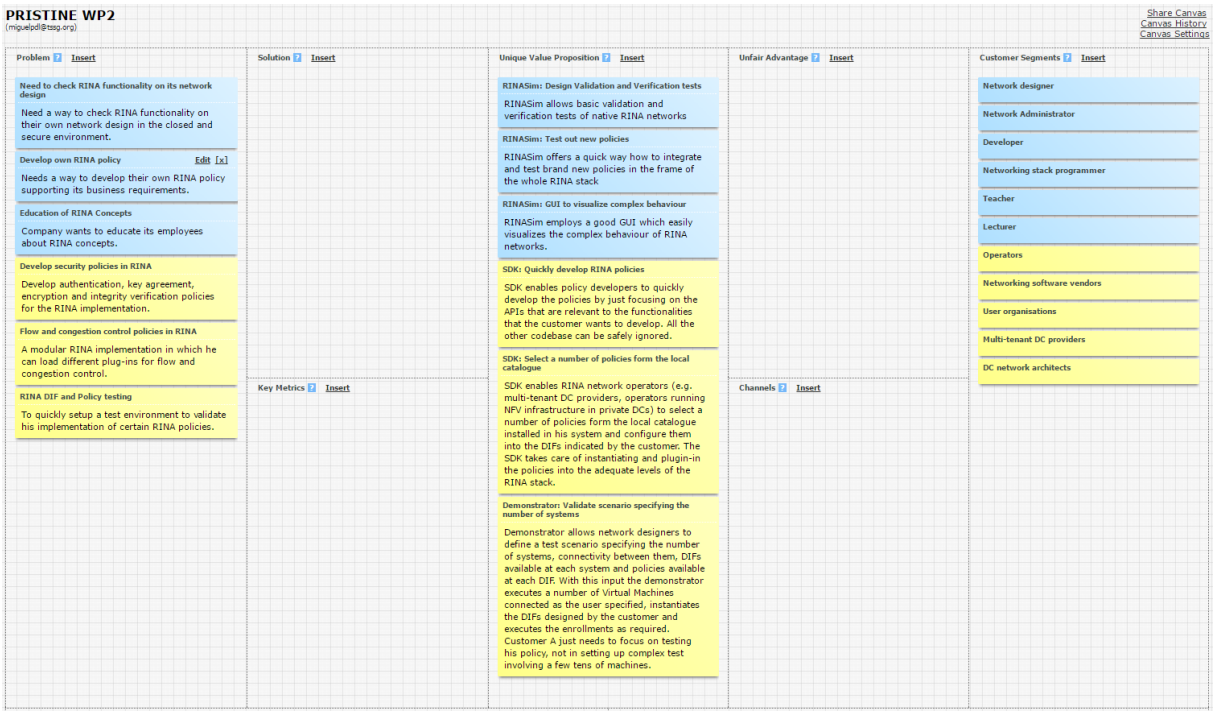

Figure 16. PRISTINE WP2 Business Model Canvas

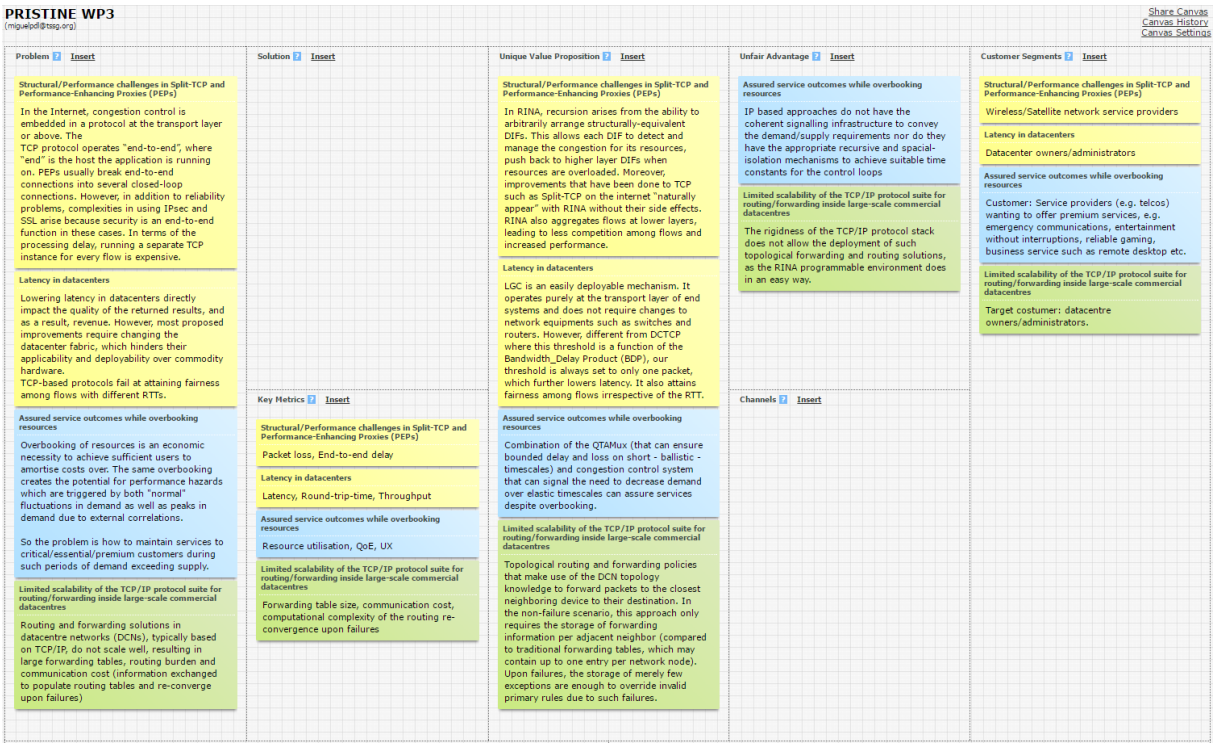

Figure 17. PRISTINE WP3 Business Model Canvas

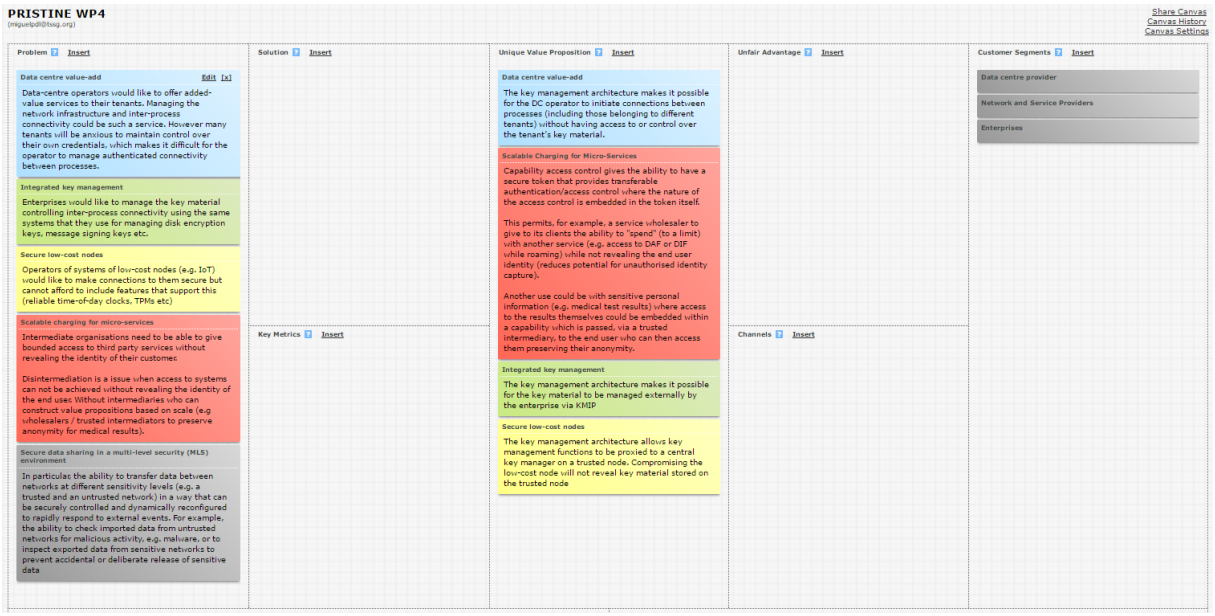

Figure 18. PRISTINE WP4 Business Model Canvas

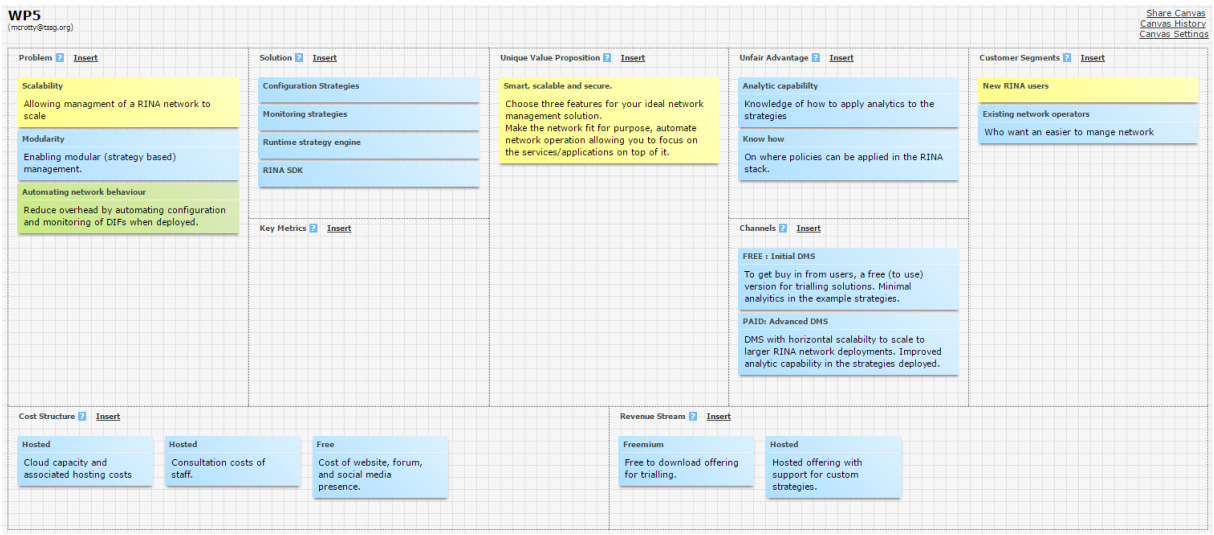

Figure 19. PRISTINE WP5 Business Model Canvas

For each technical workpackage, the online slideshow connected to picture contents is available at the following links:

- PRISTINE WP2 Business Model Canvas: available online at https://canvanizer.com/slideshow/wZcOsBGlQa2Xh
- PRISTINE WP3 Business Model Canvas: available online at https://canvanizer.com/slideshow/wzvWahckJfgU2
- PRISTINE WP4 Business Model Canvas: available online at https://canvanizer.com/slideshow/wCTJVsQaNl6nA
- PRISTINE WP5 Business Model Canvas: available online at https://canvanizer.com/slideshow/wmdmSKCqTyzGI

These canvas represent a living document which will be used by PRISTINE partners beyond the timeframe of the project to further progress the RINA business model development either on an individual basis or in small groups of partners.

4.2. Joint exploitation plans

Based on the Business Model Canvas analysis presented in the previous section, it is confirmed that three main directions exist for PRISTINE's joint exploitation strategy:

- Commercial exploitation. There is a general interest to have commercial exploitation of the results among the partners. However specific exploitation strategies differ for the industrial and academic partners, since different markets/segments are addressed. Academic partners will

consider the creation of startups that, together with other industrial partners, can be key actors in the initial RINA ecosystem.

- Research exploitation. All the partners expect to increase their know-how and IPR on the project related technologies, and eventually through patents. The identification of unexplored research topics and other technological challenges after PRISTINE's project is another major exploitation goals.
- Academic exploitation. Research centres and academics within the PRISTINE consortium will exploit the know-how acquired through the project mainly through two avenues: by designing university or master-level courses that teach the principles of networking scoping in the topics of PRISTINE, and by supervising master or PhD students on areas related to PRISTINE research.

4.2.1. Analysis of exploitable items

As previously presented in D7.3, the list of exploitable results of PRISTINE project has been maintained and upgraded, integrating the feedback and results from validation activities in WP6.

Exploitable results

Table 9. PRISTINE-1: RINA Software Development Kit (SDK)

Exploitable result id	PRISTINE-1.
Exploitable result name	RINA Software Development Kit (SDK).
Exploitation type	Commercial, Research
Work package	WP2 (T2.3).
Lead partner	Nextworks.
Other contributing partners	WIT-TSSG, I2CAT, BISDN, ATOS, iMinds.
Type of exploitable result/output	Software.
Core function of output	Enable the programmability of the RINA implementation initially started by the IRATI project and enhanced by PRISTINE. Through a well-defined API, the RINA SDK will allow developers to i) design and implement policies for the IPC Process components (delimiting, data transfer, flow control, retransmission control, relaying, multiplexing, addressing, routing, authentication, access control, encryption, etc) and ii) manage the lifecycle of these

	policies (loading, instantiation, destruction, versioning) in the systems running the RINA implementation.
Target segment for application	Users of DIFs that want to develop particular policies to be used "in-house", such as (distributed) cloud providers, distributed application platform providers or network service providers, organizations interested in researching and experimenting with RINA. Companies specialised in developing and maintaining highly-sophisticated and specialised policies for specific environments. The first segment for adoption is the current RINA researcher community, empowering them with quicker development and experimentation. As RINA matures and gains further industry interest and traction, the SDK can be aimed at wider adoption with the same value proposition towards accelerated testing and deployment.
Major benefits and impact	Enable the customization of the RINA implementation without having to understand all the stack implementation and without having to rewrite the base source code. This significantly reduces the barrier of entry and alleviates the learning curve for new adopters of RINA technology. By accelerating the larger RINA roadmap, the facilitated development and experimentation via the SDK presents an overall gain in community growth, higher adoption rate and time-to-market.
Exploitation potential from 1 (very high) to 5 (very low)	2 (high).
Current status	PRISTINE's final version of SDK in D2.5
Expected date of completion	n/a
Time to market	3-5 years
Further external collaboration	Under evaluation
Cost to exploit	Under evaluation
Protection required	SDK is GPL/LGPL in order to give more importance to software traceability and protection than faciliting the creation of commercial products. This defensive approach is driven by the immaturity of the current software and specification. When

	the RINA ecosystem becomes more stable and mature, a re-licensing will be possible to allow commercial exploitation.
IPR issues	None

Table 10. PRISTINE-2: RINA Simulator

Exploitable result id	PRISTINE-2.
Exploitable result name	RINA Simulator.
Exploitation type	Research
Work package	WP2 (T2.4).
Lead partner	FIT-BUT.
Other contributing partners	Nexedi, IMT-TSP, CREATE-NET.
Type of exploitable result/output	Software.
Core function of output	Enable the simulation of several aspects of the behavior of the RINA architecture as a whole and specific parts of it, in a single computing platform. This allows researchers interested in the RINA architecture to simulate the behavior of various components and policies before actually implementing them.
Target segment for application	Organizations interested in researching and experimenting with RINA; organizations interested in teaching the RINA model and principles (such as universities). As RINA advances its own adoption roadmap, IT organizations that are providing related solutions will be a target for simulator uptake, as well.
Major benefits and impact	Allows the simulation of the behavior of various policies at scale, as well as how different policies will interact with each other, etc. It also provides a very good tool for teaching, since students can understand step by step how RINA works, design RINA networks or simulate different configurations. The simulator represents a testing tool that will be a key component to any proof of concepts towards industry acceptance, lowering the cost of trials and offering more predictable implementations and deployments.
Exploitation potential from 1 (very high) to 5 (very low)	2 (high).

Current status	PRISTINE's final version in D2.5.
Expected date of completion	n/a
Time to market	3-5 years
Further external collaboration	Under evaluation
Cost to exploit	Under evaluation
Protection required	The software is released under the terms of MIT license.
IPR issues	None.

Table 11. PRISTINE-3: Management System for RINA networks

Exploitable result id	PRISTINE-3.
Exploitable result name	Management System for RINA networks.
Exploitation type	Commercial
Work package	WP5.
Lead partner	LMI, WIT-TSSG, BISDN.
Other contributing partners	i2CAT, TID, NXW, CREATE-NET, ATOS, TRT.
Type of exploitable result/output	Software.
Core function of output	Manage the configuration, performance and security of a RINA network - a set of DIFs distributed among a number of computer systems.
Target segment for application	Organizations wishing to setup and operate RINA networks (data centres, network service providers, distributed application providers), researchers interested in RINA network management. A systems integrator could also package the system as a solution. A comparison can be made to the market for cloud management/monitoring systems and initial SDN/NFV solutions, where the exploitation potential raises with the underlying technology adoption, in this case RINA uptake.
Major benefits and impact	Allows the configuration and monitoring of a series of DIFs distributed between a number of computer systems. Different front-ends (GUIs, Domain-Specific Languages, etc) can be built to the management system, allowing the development of different products. As software-driven networks gain traction, configuration, management and monitoring

	solutions bring gains in increased resource optimization, higher performance/QoS, lower OpEx (operational costs), and lower CapEx (re-use of hardware, less need to invest more capital). PRISTINE's impact on RINA architecture would bring similar benefits through a shared value proposition.
Exploitation potential from 1 (very high) to 5 (very low)	2 (high).
Current status	PRISTINE's final version in D5.4.
Expected date of completion	n/a
Time to market	3-5 years
Further external collaboration	Under evaluation
Cost to exploit	Under evaluation
Protection required	The software is released under the terms of MIT license.
IPR issues	None.

Table 12. PRISTINE-4: RINA Policy specifications

Exploitable result id	PRISTINE-4.
Exploitable result name	RINA Policy specifications
Exploitation type	Research
Work package	WP3, WP4, WP5
Lead partner	congestion control: UiO, security: FIT-BUT, resiliency: iMinds
Other contributing partners	ATOS, TRT, i2CAT, NXW
Type of exploitable result/output	Technical specification(s).
Core function of output	Description of policies that are used to tailor DIFs to specific use case requirements
Target segment for application	Telecom and datacenter operators
Major benefits and impact	Policies can be implemented according to these specification by different parties. The modular design of PRISTINE could allow tailor-made solutions based on the adopter's needs. Increase the research impact of PRISTINE by addressing important operating environment, like Data Centres and Internet Service Providers, that require specific policies in order to optimise/ improve their functioning.
Exploitation potential from 1 (very high) to 5 (very low)	4

Current status	Different policies have been specified: Aggregate Congestion Control, LFA for Resilient routing, QoS-aware Multipath Routing, Cherish/Urgency Multiplexing, Congestion control in datacenter-use-case, Multi-level Security.
Expected date of completion	n/a
Time to market	3-5 years
Further external collaboration	Under evaluation
Cost to exploit	Under evaluation
Protection required	Specifications are available in public deliverables.
IPR issues	None

Table 13. PRISTINE-5: Integrated RINA PoC for the distributed cloud use case

Exploitable result id	PRISTINE-5.
Exploitable result name	Proof of concept of the distributed cloud use case.
Exploitation type	Commercial
Work package	All WPs.
Lead partner	i2CAT, Nexedi.
Other contributing partners	FIT-BUT, Nextworks, iMINDS.
Type of exploitable result/output	Software and scenario configuration.
Core function of output	RINA stack and policies for the distributed cloud use case, implementing a cloud networking infrastructure consisting in two levels of DIFs (cloud DIF and backbone DIF), supporting different tenant DIFs for different customers. Policies in the cloud provide authentication, encryption, scalable routing, congestion control and differentiated traffic treatment for both delay and loss.
Target segment for application	Decentralized cloud services. Cloud computing.
Major benefits and impact	Customizable, dedicated networking environment running over a decentralized cloud infrastructure designed to provide enhanced resiliency and privacy compared to traditional cloud offerings. The parallel deliverable D6.2 addresses an initial impact assessment of the three use cases.

Exploitation potential from 1 (very high) to 5 (very low)	1 (very high).
Current status	Final release of authentication and encryption policies ready (as of June 2016). Congestion avoidance policies ready.
Expected date of completion	n/a.
Time to market	3-5 years
Further external collaboration	Under evaluation
Cost to exploit	Under evaluation
Protection required	Software bundle composed by the IRATI implementation (GPL, LGPL) and policies for the use case (GPL, MIT).
IPR issues	None.

Table 14. PRISTINE-6: Integrated RINA PoC for the datacentre networking use case

Exploitable result id	PRISTINE-6.
Exploitable result name	Integrated PoC for the datacentre networking use case.
Exploitation type	Commercial
Work package	All WPs.
Lead partner	CREATE-NET, ATOS.
Other contributing partners	NXW.
Type of exploitable result/output	Software and scenario configuration.
Core function of output	An integrated sofware package to be deployed in a datacenter scenario. The RINA architecture can have a technical impact on the services in terms of efficiency, security and costs, as well as a business impact that deployment may have in terms of new business opportunities and new added-value services on top of the network.
Target segment for application	Data Center, Virtual Data Center applications, Data Center Network Providers
Major benefits and impact	The integration of RINA with existing hypervisors could simplify and speed up the configuration, administration and tear down of virtual networks while lowering the RINA adoption barrier in the current scenarios. Resource optimization and performance gains would lower OpEx and increase QoS. Key management system

	is essential to enable the implicit security benefits of RINA to be usable in large-scale real-world deployments.This offers an opportunity to both datacenter operators or datacenter network providers (direct adoption) and systems integrators to offer as a solution for that customer segment. The parallel deliverable D6.3 addresses an initial impact assessment of the three use cases.
Exploitation potential from 1 (very high) to 5 (very low)	1 (very high).
Current status	Final phase of experiments completed, results published in D6.3
Expected date of completion	n/a
Time to market	3-5 years
Further external collaboration	Under evaluation
Cost to exploit	Under evaluation
Protection required	Software bundle composed by the IRATI implementation (GPL, LGPL) and policies for the use case (GPL, MIT).
IPR issues	None

Table 15. PRISTINE-7: Integrated RINA PoC for the network service provider use case

Exploitable result id	PRISTINE-7.
Exploitable result name	Integrated demonstrator of RINA for ISPs.
Exploitation type	Commercial
Work package	All WPs.
Lead partner	Telefonica, iMinds
Other contributing partners	
Type of exploitable result/output	Software and scenario configuration.
Core function of output	Demonstrate PRISTINE concepts to stakeholders interested in new architectures for Internet Service Provider. The same outcome is also intended to be used for research and education purposes.
Target segment for application	Telecom providers.
Major benefits and impact	See PRISTINE in action, assess potential. The parallel deliverable D6.2 addresses an initial impact assessment of the three use cases.
Exploitation potential from 1 (very high) to 5 (very low)	1 (very high).

Current status	Completed
Expected date of completion	n/a
Time to market	3-5 years
Further external collaboration	Under evaluation
Cost to exploit	Under evaluation
Protection required	Software bundle composed by the IRATI implementation (GPL, LGPL) and policies for the use case (GPL, MIT).
IPR issues	None

Table 16. PRISTINE-8: Boundary Protection Component for Multi-Level Security

Exploitable result id	PRISTINE-8.
Exploitable result name	Boundary Protection Component for Multi-Level Security.
Exploitation type	Commercial, Research
Work package	WP4.
Lead partner	TRT-UK.
Other contributing partners	-
Type of exploitable result/output	Software Component
Core function of output	This exploitable function enables data to be sent between classification levels in a carefully controlled and secure way to prevent accidental or deliberate release of sensitive data. It integrates the functionality of a Boundary Protection Component (BPC) into a RINA-based network to achieve the above. The intended use of this is to allow a controlled flow of data between security levels in a RINA network, while ensuring that data transferred the sending system is at a suitable classification level for the receiving system.
Target segment for application	Service and Network Providers
Major benefits and impact	The needs for MLS have emerged as organisations have had to deal with securing and protecting separate networking environments having different security classifications. This model no longer supports the needs for real-time communication, situational awareness and rapid response to crisis in the modern communications era. With MLS-BPC, it is possible to provide cross-domain

	information sharing across multi-domain security environments where each domain is managed by a separate administration authority.
Exploitation potential from 1 (very high) to 5 (very low)	2
Current status	Laboratory component implemented.
Expected date of completion	n/a
Time to market	3-5 years
Further external collaboration	Under evaluation
Cost to exploit	Under evaluation
Protection required	Is being timestamped and protected. The licensing issue is under discussion internally.
IPR issues	None.

The same tables have been used in the per-partner exploitation plans reported in the following sections, in order to ease the analysis of the inputs as well as grouping the results towards defining the first iteration of the PRISTINE' exploitation plans.

4.2.2. IPR and Licensing

Deliverable D7.3 contains an analisys of those aspects related to Intellectual Property rights, in order to define a strategy that could allow the widest distribution, usage and adoption of RINA software, while guaranteeing - at the same time - appropriate authorship rights. This section reports the updates related IPR and licensing strategy that were planned in D7.3.

Patents

Most of the RINA core developments in PRISTINE are published under Open Source license schemes as detailed in the next section. However, Thales UK has started internal procedures for patent application on the "Boundary Protection Component for Multi-Level Security" they have developed through WP4 activities. This foreground is owned by Thales UK only and is substantially orthogonal to the RINA core elements, since it addresses the cross-domain information sharing across multi-domain security environments. The process for patent filing is ongoing within Thales UK and will progress after the end of the PRISTINE project.

Licensing

As a general licensing strategy, PRISTINE pursues a balance between protection and adoption. On the one hand, GPL is preferred for the core RINA functions, in order to ensure that modifications of the open source code are made public; on the other hand, the SDK was designed to allow closed-source policy plugins for industry-aimed solutions. This balanced strategy has been judged the best path to achieve both good RINA dissemination and proper project exploitation, taking into account the feedback received from the partners during the first iteration of the project. IPRs and licenses attached to PRISTINE's software and specifications have been discussed within the consortium.

The different software assets within PRISTINE have been classified in three areas:

1. Extensions (e.g. SDK, Management Agent, IRATI demonstrator) or improvements (e.g. bug fixing, hardending, refactoring) of IRATI software.
2. Custom (non default) plugins to implement PRISTINE policies and related specifications.
3. Other software modules outside IRATI, e.g. the Network Manager (WP5) or RINA simulator.

Final status of licenses and IPRs

The following table reports a list of the licensed items and for each of them it is specified:

- Software module: Name of the software module to be licensed
- Component: RINA components involved in the software module
- Research area: Research area involved in the software module
- License: License currently associated with the software module
- Copyright holder: Partner that holds the software rights
- Dependencies & Licenses of the dependencies: libraries and binaries that the software module depends on, and their corresponding licenses

Table 17. Table of Licenses

Software Module	Component	Research area	License	Copyright holder	Dependencies & Licenses of the dependencies
librina (part of IRATI/ SDK)	ALL	ALL	LGPL	NXW, i2CAT, iMinds	
rinad (part of IRATI/SDK)	ALL	ALL	LGPL	NXW, i2CAT, iMinds, BISDN	
IRATI/ SDK kernel support	ALL	ALL	GPL	NXW, i2CAT, iMinds	
rina-tools (part of IRATI/SDK)	ALL	ALL	BSD	NXW, i2CAT, iMinds, BISDN	
Aggregate Congestion Control	RMT, DTCP	Congestion control	GPL	UiO, i2CAT	None
LFA for Resilient routing	RMT, RA, Routing	Routing, Security coordination	GPL	NXW, iMinds	None
QoS-aware Multipath Routing	RMT, RA, Routing	Routing	LGPL (temporary)	ATOS	None
Cherish/ Urgency Multiplexing	RMT	Resource allocation	GPL	UPC, i2CAT	None
Congestion control in datacenter-use-case	RMT, DTCP	Congestion Control	GPL	CREATE-NET	None
Multi-level Security	Security Manager (BPC)	Security coordination	Under internal discussion at TRT (Proprietary)	TRT	To be specified
Secure channel	SDU Protection	Security	GPL	FIT-BUT	Linux Crypto API - GPL

Software Module	Component	Research area	License	Copyright holder	Dependencies & Licenses of the dependencies
implementation Mechanisms and Policies					
Authentication policies	CACEP, Security coordination	Authentication, security coordination	LGPL	i2CAT	librina, LGPL
RINASim	simulator	simulation	MIT	FIT-BUT	OMNeT++ license http://www.omnetpp.org/intro/license
Network Manager	Manager of RINA-enabled systems	Network Management	Open source License (to be decided)	Ericsson, others?	None
Management Agent	Management Agent for the IRATI RINA implementation	Network Management	GPL	BISDN, i2CAT, Nextworks	rinad - GPL; librina - LGPL
Traffic Generator	Research tool for experimentation	Integration	GEANT outward Software License	iMinds, NXW	none, links with BOOST C++ libraries
IRATI demonstrator	Tool for automated deployment and testing for the IRATI stack	Integration	GPL	NXW	None

Licensing updates

The final status of licenses for the IRATI software reflects the status of that software as released at the end of the PRISTINE project (October 2016). To realise the plans, the following modifications have been carried out by means of re-licensing:

- rinad has migrated from GPL to LGPL, to allow other PRISTINE's partners and third parties to develop closed-source user-space plugins.

In fact, PRISTINE SDK allows for custom policies to be plugged into the daemon processes contained in rinad (the IPC Process user-space implementation, the IPC Manager and the Management Agent). Since plugins are linked against rinad, the previous rinad license (GPL) forced the plugins to be GPL. This was in contrast with PRISTINE commercial exploitation plans, that are fostering future commercialization of custom policies, in the form of binary plugins.

- rina-tools has been re-licensed with BSD license in place of GPL. The rina-tools package contains small utilities (e.g. rina-echo-time) that are used to debug/test the IRATI software. On one hand those utilities are not particularly important or central to PRISTINE, and therefore switching towards a more permissive license is not really required. On the other end it is expected that PRISTINE's partners and third parties (e.g. future research projects) can use these small application as a starting point for developing their native RINA applications. For this reason, having these tiny applications as BSD code can possibly avoid future licensing problems.

Regarding other software not included in IRATI (RINASim, Network Manager, custom plugins), no license updates are to be reported with reference to D7.3. The Management Agent, implemented as an optional component of the IPC Manager Daemon, simply inherits the rinad license (LGPL).

4.3. Individual exploitation plans

The following paragraphs present the individual partner exploitation plans. Each section contains a short description of the partner and its interest, as well as the opportunities the partner sees for exploiting results developed within PRISTINE.

Analysis and information is provided in the tabular format introduced in Analysis of exploitable items.

4.3.1. Atos

As a large IT provider, Atos invests in research objectives of various timelines and levels of ambition. For example, several projects are aimed at readying an advanced prototype or proof of concept with an initial market potential within a few years after initial development. Others are more

far reaching strategic objectives of several years, sometimes applying to a market transition that have not yet taken form. PRISTINE is of the latter.

Atos recognizes the potential of PRISTINE, and its extension of the RINA architecture, as a potential long-term disruptive technology for the core evolution of networks. The company's exploitation development for the project involves highlighted scenarios of varying timelines and dependencies, also syncing with its larger 5G-related R&D roadmap.

The first scenario, Cloud / Data Center Management, relates to a more local application of the architecture (i.e. LAN, between company sites, or between company and customer), while the latter two scenarios are further reaching, meeting a potential wider impact of RINA across external networks. The multiple timelines are taken to compensate for various RINA adoption challenges:

- The Recursive Internet (RINA) concept is very disruptive, while TCP/IP is a very well established, requiring a longer term strategy to facilitate adoption.
- Technology readiness is below TRL 6. There are currently no production deployments of RINA yet and projects like PRISTINE are still studying practical solutions for unexplored aspects related to the fragmentation of processes that RINA proposes.
- Industrial involvement is at an early stage, and requires a more pragmatic demonstration of RINA potential through viable pilots; such as the project's SDK and use cases are designed to help achieve.

Scenario #1: Network Improvement of Cloud Computing Portfolios and Data Center Management

- Estimated Timeline: 2 to 5 years starting with proof of concept towards company's data centers. Atos has an established and growing Cloud computing portfolio that has become a core priority for the company.

The Canopy brand, originating from a joint venture between Atos, VMware and EMC, includes Infrastructure, Platform and Software as a Service (IaaS, PaaS and SaaS), as well as leadership in large enterprise consulting. The acquisition of Bull in 2014 has brought even more resources to the Cloud, Cyber-security and Big Data focus of the group.

The company focuses on end-to-end service lines for its Cloud computing offerings. For example, this could begin with consulting, leading to implementation of a private Cloud integrated at the customer, and expanded into a hybrid solutions (private/public) at Atos data centers, or full managed operations of the deployment. The combinations are numerous, with several IaaS and PaaS offerings of different tenancy options, of local, hybrid and fully managed variations.

As the Cloud offerings mature in flexibility, resulting in the interlinking of several infrastructures or platforms between data centers, the network requirements become increasingly complex. PRISTINE includes two use cases examining this area: Distributed Cloud and Datacenter Networking, bringing substantial improvements to routing and distributed resource allocation for more cost-effective operation and QoS for hosted customer applications, in addition to increased security as these scenarios become more and more distributed. For example, the Datacenter Networking use case recognizes IP bottlenecks in relations to management and mobility of VMs between sites, congestion issues, multi-tenancy complexity, etc.

These scenarios represent an area where Atos can exploit PRISTINE without the larger dependencies of a wider adoption and disruption, where such qualities can be implemented exclusively between company sites.

Atos exploitation of PRISTINE towards these scenarios has started with its close collaboration in WP2 use cases and WP6 evaluation scenarios in the context of business impact.

As the final demos in the project are already available, Atos will continue dialog with its counterparts in datacenter management, Cloud portfolios (Canopy, Bull) and managed operations, leveraging the impact analysis and results obtained in WP6 and identifying the building blocks for a potential proof of concept.

This internal evaluation will lead to a roadmap for further trial and potential adoption of the technology.

Table 18. Exploitation entry

Exploitable results number	For management between datacenter sites: * PRISTINE-3: Management System for RINA Networks * PRISTINE-4: RINA Policy Specifications

	For programmability and testing of network: * PRISTINE-1: RINA Software Development Kit (SDK) * PRISTINE-2: RINA Simulator For general requirements, PoC, know-how, etc. * PRISTINE-5: Integrated RINA PoC for the Distributed Cloud Use Case * PRISTINE-6: Integrated RINA PoC for the Datacenter Networking Use Case
Target segment for application	This scenario is aimed at improving Cloud computing offerings at Atos, aimed at a variety of customer profiles in industry verticals (e.g. finance, transport, health, retail, manufacturing, etc.). It would not be disruptive to existing IaaS and PaaS business models, but instead improve the performance, OpEx and overall competitiveness of the offerings.
Major benefits and impact	The socio economic impact of the scenario is initially targeted at the company's operations: cost savings (decreased OpEx), reliability (interlinking data center network), security, etc. Benefits would then be delivered to the customer through improved IaaS and PaaS offerings, following the Cloud computing value chain. Customers of Atos' Cloud computing offerings would benefit from improved performance and QoS of applications and services deployed and federated between Atos data centers' distributed infrastructure.
Current status	Under evaluation
Expected date of completion	1 to 4 years additional development, simulation and proof of concept of architecture concepts for company's data centers.
Time to market	As mentioned above, in a 1 to 4 year timeline that includes internal proof of concepts, aspects of certain PRISTINE / RINA architecture could be used internally at data center operations. As technology

	receives more traction, “Time to Market” in this case refers to when existing offerings would be upgraded with project assets as an alternative, rather than a standalone service line.
Further external collaboration	Continued participation with RINA-related working groups and initiatives will be key. As PRISTINE is Atos' first experience with RINA, this continued collaboration is on the critical path for any exploitation scenario.
Cost to exploit	Internal follow-up PoC and related integration costs will be a company project, independent of additional funding. However, participation in continued research initiatives would be approached in Atos’ R&D department, as RINA implementation is still in the research domain, as opposed to a high TRL prototype closer to production use.
Protection required	GPL licensing for the protocol stack and MIT licensing for the simulator has been selected within the project. An open source license would have been the preferred path commercially speaking, but technically speaking there were some restrictions regarding the protocol stack. This combination should not limit the integration potential.
IPR issues	GPL licensing has been used for the protocol stack. This will facilitate the integration with the Linux kernel. For the simulator, MIT licensing has been selected in order to be more viable for the industry.

Scenario #2: Telecom Sector Consulting and System Integration

- Estimated Timeline: 2-6 years of long-term technology forecast/ consulting and later more tangible opportunities in potential systems integration.

Under the Atos Consulting brand, the company focuses on internal technology and knowledge transfer of such projects to support clients in commercializing innovative products and services. In the telecom sector in particular, the arena has expanded with new technologies that have permeated the market. Network Function Virtualization (NFV), for

example, is readying an increased role for IT providers, such as Atos, in a 4-8 year span in increased adoption from telecom customers, leveraging experience in virtualization from its Cloud service provision as network providers break their dependence on hardware-centric solutions and move towards a more agile software-driven strategy.

PRISTINE offers a longer-term consulting and systems integration opportunity that can be dovetailed in its increased role in software-driven networks and 5G vision.

This scenario has a wide range in timeline, as the company's consulting also deals with longer-term disruptive technology when advising its customer base. As PRISTINE and RINA's influence increases over time, more hands-on services can be coupled with its other network technologies of more short and mid term time-to-market projections, such as NFV.

Next Steps:

1. Increase dissemination internally to the company, hosting presentations of PRISTINE's potentially disruptive impact.
2. Further industry-level dissemination in 5G-PPP arena to help close technology gap.
3. Collaboration with consulting teams as PRISTINE / RINA aspects further permeate networks.

Table 19. Exploitation entry

Exploitable results number	For experience and know-how of PRISTINE/RINA-based network solutions: * PRISTINE-1: RINA Software Development Kit (SDK) * PRISTINE-2: RINA Simulator * PRISTINE-3: Management System for RINA Networks * PRISTINE-4: RINA Policy Specifications For best practices, general requirements of PRISTINE/RINA implementation: * PRISTINE-5: Integrated RINA PoC for the Distributed Cloud Use Case

	* PRISTINE-6: Integrated RINA PoC for the Datacenter Networking Use Case
Target segment for application	This scenario is aimed at the Telecom Sector through Atos consulting and systems integration services.
Major benefits and impact	As recursive networks break through the research domain and gains market traction, Telecom Sector customers, such as network operators, will benefit from consulting services by companies with context gained during related research initiatives and PoCs. The socio economic impact of the scenario is focused on consultancy and ease-of-integration of recursive networks, suggesting the ability to make better educated business decisions (refined requirements, scope of integration, etc.) and lower cost of entry (ease of integration by experts of the technology, etc.), respectively.
Current status	This is a farther off exploitation goal, when PRISTINE/RINA research experience can be translated to business consultancy and systems integration, which depends highly on the long-term maturation and adoption rate of RINA.
Expected date of completion	2-6 years, a wide estimation that depends on long-term adoption of RINA.
Time to market	Such services would be ideal to introduce immediately to first-movers from the Telecom Sector, as consultancy of the emerging technologies would be rare service due to its incubation in the research domain.
Further external collaboration	Continued participation with RINA-related working groups and initiatives will be key for any such scenario.
Cost to exploit	The costs of delivering consultancy or integration services is difficult to quantify given the distance to actual market introduction of PRISTINE/RINA. As many such services, this will depend heavily on the individual requirements and scope of each telco customer.
Protection required	(repeated from previous scenario, universal for all exploitation paths) GPL licensing for the protocol stack and MIT licensing

	for the simulator has been selected within the project. An open source license would have been the preferred path commercially speaking, but technically speaking there were some restrictions regarding the protocol stack. This combination should not limit the integration potential.
IPR issues	(repeated from previous scenario, universal for all exploitation paths) GPL licensing has been used for the protocol stack. This will facilitate the integration with the Linux kernel. For the simulator, MIT licensing has been selected in order to be more viable for the industry.

Scenario #3: Strategic Positioning in Disruptive Technologies

- Estimated Timeline: 2-10+ years, beginning with SDK and growing in relevance in parallel to larger PRISTINE / RINA adoption and disruption.

Atos remains competitive by a proactive approach towards new technologies, hence its large investment in research and innovation, and links with longer term IT business opportunities, such as 5G-related R&D.

PRISTINE's fully realized impact is ambitious, helping to evolve the internet to foresee the industry and society's future requirements. A standardization roadmap is developing in the project, and will help support the architecture's larger advancement and adoption path.

Atos has supported during the project this effort with consistent dissemination and education of the PRISTINE's results. The SDK, in particular, can be recognized as a building block allowing the creation of more advanced use cases to realize its potential, and bringing the technology from an academic domain to more pragmatic, concrete trial scenarios. This a circular impact, where increased experimentation of the SDK will lead to a stronger business case for supporting the wider disruptive path of the architecture, and vice versa.

Atos will leverage the SDK towards future R&D, positioning the company in a supporting role of RINA's concepts. The ROI of this strategic support will be a competitive positioning as the architecture's adoption increases.

Next Steps:

1. Exploitation of the SDK within the company's R&D department for further use cases and trials based on PRISTINE's extension of RINA architecture.
2. Continues dissemination of SDK and project's results to both internal (company) and external (IT sector, 5G-PPP and related initiatives) to maintain Atos growth in long-term network technologies.

Table 20. Exploitation entry

Exploitable results number	For additional experimentation for research: * PRISTINE-1: RINA Software Development Kit (SDK) * PRISTINE-2: RINA Simulator For base components for continued extension: * PRISTINE-3: Management System for RINA Networks * PRISTINE-4: RINA Policy Specifications For existing use cases and baselines to create new PoC's * PRISTINE-5: Integrated RINA PoC for the Distributed Cloud Use Case * PRISTINE-6: Integrated RINA PoC for the Datacenter Networking Use Case
Target segment for application	This scenario is aimed at strategic positioning around a potentially disruptive technology, beginning with the extension of research using the SDK, possibly leading to additional PoCs. Given the wide impact of potential longer-term, RINA-related adoption, this could eventually apply to a variety of sectors, gaining traction with further support from network providers and stakeholders in the Telecom sector. For now this is still limited to the growing RINA community, and the larger industry awaits further trials and validation, which PRISTINE is helping to move forward.
Major benefits and impact	This is a cumulative and longer-term collection of benefits from the other

	scenarios, whereas Atos would be able to position itself strategically for a potential widespread adoption of RINA architecture in networks. This would focus on a Telecom sector customer base and other verticals that would need consultancy, integration, service deployment, etc., on their RINA-enhanced networks, or, depending on adoption potential, the larger internet. The socio economic impact of the scenario is more focused on the research domain given its timeline and distance from its most disruptive adoption scenarios. Support for a larger PRISTINE / RINA roadmap, through extension of the core architecture, experimentation with the SDK and additional PoCs, would at its fullest help realize its vision of improving network technology in terms of QoS, efficiency, security, growth, etc.
Current status	This is a farther off research, experimentation and leadership goal, awaiting external dependencies such as PRISTINE / RINA adoption on a more standardization-related roadmap. Although this longer-term roadmap depends greatly on the larger RINA community, additional research and trials through this scenario can help speed its progress.
Expected date of completion	3-10+ years, a wide estimation that depends on long-term adoption of RINA.
Time to market	Time to market is a far off objective, where this scenario focuses on the potential of widespread adoption / overhaul of networks via an iteration of RINA architecture.
Further external collaboration	Continued participation with RINA-related working groups and initiatives will be key for any such scenario. Additional collaborative PoCs would avoid risk of silos, given that RINA success depends largely on a community effort.
Cost to exploit	In this case, the cost would be a combination of company-invested research and additional funded research.
Protection required	(repeated from previous scenario, universal for all exploitation paths) GPL licensing

	for the protocol stack and MIT licensing for the simulator has been selected within the project. An open source license would have been the preferred path commercially speaking, but technically speaking there were some restrictions regarding the protocol stack. This combination should not limit the integration potential.
IPR issues	(repeated from previous scenario, universal for all exploitation paths) GPL licensing has been used for the protocol stack. This will facilitate the integration with the Linux kernel. For the simulator, MIT licensing has been selected in order to be more viable for the industry.

4.3.2. BISDN

BISDN role in PRISTINE is primarily focused on the network management aspect of PRISTINE (WP5) and the authentication and authorization policies in the context of WP2. It is also involved in the general software stack development, which is a cross-WP activity.

BISDN will explore the feasibility to design and develop two different solutions:

Table 21. Exploitation entry 1

Exploitable results number	BISDN-1
Exploitable result name	Hardware accelerated RINA router
Exploitation type	Commercial
Work package	All WPs
Type of exploitable result/output	Software and hardware
Target segment for application	Data Centres and Service Providers
Major benefits and impact	Increased performance for RINA routers, that can benefit from the advantages/ flexibilites of RINA. BISDN has (parallel to PRISTINE) developed skills in programming the forwarding plane for whitebox datacenter switches. The discussions with the partners during the project will be leading to a next-gen OpenStack networking solution. Further alignment between the opportunities given by the silicon pipeline and the RINA architecture is needed, as the hardware

	pipeline is Ethernet-restricted. Latest additions in programmability to the pipeline will allow new packet header formats, eventually leading to a clean RINA implementation. As an intermediate solution, an Ethernet-based RINA layer will be developed.
Exploitation potential	2
Current status	Start planned for Q3 2017 discussion
Time to market	2-5 years, depending on RINA adoption.
Further external collaboration	None forseen yet
Cost to exploit	Under evaluation
Protection required	To be defined
IPR issues	None.

Table 22. Exploitation entry 2

Exploitable results number	BISDN-2
Exploitable result name	RINA-based ISP transport solution
Exploitation type	Commercial
Work package	WP2, WP5
Type of exploitable result/output	Software
Core function of output	A more manageable and robust ISP access network transport solution
Target segment for application	ISP and access networks
Major benefits and impact	Improved manageability, reduced operational costs and CAPEX. Improvement of user's quality of experience.
Exploitation potential	2
Current status	Under discussion
Time to market	+5 years
Further external collaboration	To be defined
Cost to exploit	Under evaluation
Protection required	To be defined
IPR issues	None

4.3.3. CREATE-NET

CREATE-NET is a research center that pursues innovation among its key objectives, with an ever increasing focus on services. CREATE-NET is already working on five spin-offs coming from past FP7 research projects; local public bodies are encouraging and supporting these

initiatives. Furthermore, through its EIT ICT Labs involvement, CREATE-NET has been able to attract angel funds investment for its start-ups. The innovations from PRISTINE will be candidate for further business exploitation within new in spin-offs. CREATE-NET is also working closely with local service providers and network operators within the framework of the local Trentino testbed initiative where some of the innovative concepts developed within the project will be tested. Validation strategies will be jointly identified for future adoption of the PRISTINE concepts within the local region. Moreover, CREATE-NET, as an official member of the EIT ICT Labs initiative, will identify exploitation opportunities together with key stakeholders in the consortium to ensure faster go-to-market opportunities and other potential adopters of the PRISTINE concepts and technologies.

CREATE-NET's exploitation plan is structured along two dimensions: (i) industrial exploitation, and (ii) academic exploitation. With the former, CREATE-NET will leverage on the competences and IPRs generated during the PRISTINE project in future industrial projects. Regarding the latter (academic exploitation) CREATE-NET integrated the fundamental RINA concept in curriculum of the Wireless Networks course (M.S.).

Academic exploitation

Table 23. Exploitation entry

Exploitable results label	CREATE-NET-1
Exploitable result name	M.Sc. Course
Exploitation type	Academic
Type of exploitable result/output	M.Sc. course material
Target segment for application	Academy
Major benefits and impact	Introduce students to RINA, filling the current gap in M.Sc. level courses on recursive internet architectures. Educating students to RINA concepts will help fostering wider adoption.
Exploitation potential	3
Current status	A four hours seminar on RINA was given to the students of the Wireless Networks Course (M.Sc., University of Trento)
Expected date of completion	June 2015
Time to market	N/A

Further external collaboration	None
Cost to exploit	N/A
Protection required	No
IPR issues	None

4.3.4. Ericsson

Work in PRISTINE can be exploited Ericsson along three main directions.

The first is the evaluation of PRISTINE results as direct input into Ericsson product roadmaps, namely for the network management software the LMI is responsible for. The main product here is the Ericsson Network Manager - ENM, which was announced in 2013 and is now increasing its install base world-wide.

The second direction is to use RINA to create wide industry awareness on clean slate approaches for network management. We will continue working closely with the PSOC (also through the ARCFIRE project and beyond) to harmonize the PSOC RINA standard series with activities of other industry standard bodies, e.g. those concerned with autonomic networks (TMF Forum) and those related to 5G networks and services (ETSI and 3GPP).

The third activity will be our active contribution to RINA related open source programmes. We believe that this is a very important, yet not classic exploitation activity, which carries the possibility of a wide uptake of RINA operator networks in academia and industry, beyond multi-national, research-heavy companies such as ourselves. We'd hope that this activity will help to create a wide user base for RINA operator networks.

These three areas of activities will be realised in close cooperation with Ericsson Research.

4.3.5. FIT-BUT

FIT-BUT mostly focus their exploitation plans along academic initiatives, with some actions just started and reported in the following table.

Table 24. Academic exploitation

Partner	Type [a]	Starting date [b]	Ending date [c]	Topics
FIT-BUT	PhD	Q3 2013	Q3 2017	Data transfer in Recursive

Partner	Type [a]	Starting date [b]	Ending date [c]	Topics
				Network Architectures
FIT-BUT	PhD	Q3 2014	Q3 2018	Secure channel and data transfer
FIT-BUT	Bc	Q3 2014	May 2015	RMT and RA simulation modules
FIT-BUT	Bc	Q3 2014	May 2015	Enrollment and authentication process

[a] Phd or MSc
[b] Expected starting date
[c] Expected ending date

The main actives of FIT-BUT aim at research and evaluation of the PRISTINE concepts using simulation techniques the exploitation consists of RINA simulator tool being developed in the project.

Table 25. Exploitation entry

Exploitable results number	PRISTINE-2
Exploitable result name	RINA Simulation tool
Exploitation type	Research
Work package	WP2
Lead partner	FIT-BUT
Other contributing partners	IMT-TSP, CREATE-NET
Type of exploitable result/output	Software
Core function of output	RINA simulation model for OMNet++ simulator in the form of a collection of RINA component models and predefined RINA nodes and a set of scenarios. It is possible to simulate RINA networks to demonstrate functionality and perform experiments with different policies and under various settings and constraints.
Target segment for application	Academy
Major benefits and impact	To better understand networking architectures based on RINA and analyze the properties of the different communication mechanisms within RINA. The simulation environment may be used

	for obtaining results to support research and also as a demonstration environment in education.
Exploitation potential	3
Current status	A complete beta version of RINA Simulation tool is already available.
Expected date of completion	30.10.2016
Time to market	Because of the character of the output and target segment, this output can be successfully used even before it is completed.
Further external collaboration	Possible, depending on the interest of RINA community.
Cost to exploit	No
Protection required	This output will be available under public domain, and distributed under MIT license.
IPR issues	None

Table 26. Exploitation entry

Exploitable results number	FIT-BUT-1
Exploitable result name	Ph.D. Project
Exploitation type	Academic
Work package	WP4
Lead partner	TRT
Other contributing partners	
Type of exploitable result/output	Ph.D. Thesis
Core function of output	Except new theoretical results the output will consist of a set of methods and policies of RINA security accompanied with implementation. New results on security mechanisms that include authentication, access control and encryption in IPC-based network architecture.
Target segment for application	Academy
Major benefits and impact	New research results in the area of security in IPC environment.
Exploitation potential	2
Current status	Ph.D. project started in September 2014. Currently, the research is in progress with some preliminary results available.
Expected date of completion	Ph.D. Thesis completed and defended in the year 2018.

Time to market	N/A
Further external collaboration	The Ph.D. project will continue after finishing PRISTINE project. External collaboration is possible.
Cost to exploit	N/A
Protection required	No
IPR issues	None

Table 27. Exploitation entry

Exploitable results number	FIT-BUT-2
Exploitable result name	Ph.D. course
Exploitation type	Academic
Work package	WP3, WP4, WP5
Lead partner	TRT
Other contributing partners	
Type of exploitable result/output	MSc course material
Target segment for application	Academy
Major benefits and impact	To present the current state in networking, identify challenges and possible solutions. To provide a deep elaboration on possible outcomes.
Exploitation potential	2
Current status	Gathering information and compiling course materials.
Expected date of completion	End of 2016 (course will be prepared to teach during academic year 2017/2018)
Time to market	N/A
Further external collaboration	Any interested partner of the project. Supported from mobility grants.
Cost to exploit	N/A
Protection required	No
IPR issues	None

4.3.6. i2CAT

i2CAT is the PRISTINE technical project coordinator and WP2 co-leader, leveraging its 3 years of experience participating in the international RINA effort. i2CAT periodically presents project outcomes among its board members, composed by a variety of Internet stakeholders: manufacturers - Cisco, Juniper, Alcatel, Fujitsu -, operators - Vodafone, Orange, Abertis

– and content providers - Mediapro, Cromosoma. In these review events, the i2CAT RINA team tries to promote the involvement of the board members in RINA initiatives, pushing for the creation of a spin-off company specialised on RINA products and services.

As such this general exploitation strategy can be broken down into the following more detailed items.

Table 28. i2CAT exploitable result 1

Exploitable results	PRISTINE-1: RINA Software Development Kit (SDK)
Exploitation type	Research, training and consulting activities (commercial)
Target segment for application	Competitive research funding calls for proposals; organizations desiring to acquire RINA knowledge
Major benefits and impact	Customizable RINA reference implementation, allowing for quick prototyping of policies and setting up RINA demos/trials
Current status	RINA implementation with full-fledged SdK ready. Being used an improved in H2020 ARCFIRE project.
Expected date of completion	Completed as per PRISTINE goals, being further improved within ARCFIRE (robustness, stability, support for mobility - WiFi)
Time to market	Immediate for competitive research calls for proposals - being already exploited by ARCFIRE; 6 months to 2 years after the project ends for the consulting activities
Further external collaboration	Depending on the needs of the competitive research call or the customers, collaboration with partners that have RINA knowledge (such as the ones in the PRISTINE consortium) is foreseen. In the case of ARCFIRE, i2CAT is collaborating with Nextworks, Telefonica, Ercisson, iMinds and Boston University.
Cost to exploit	Can be exploited right away as a tool to be used in RINA research proposals. Cost to exploit for consulting activities depends on the specific activity, but at least effort must be devoted to pre-package a series of demos

	that are self-contained, can be setup via scripts and show the main RINA benefits.
Protection required	Software has open source licenses as described in the Licensing section
IPR issues	No issues identified

Table 29. i2CAT exploitable result 2

Exploitable results	RINA product based on any of the three PoCs
Exploitation type	Commercial
Target segment for application	Datacentre operators, telecom operators wishing to implement service function chaining, distributed IT infrastructure providers
Major benefits and impact	Flexible, customizable networking solution with specific security, multiplexing, data-transfer and routing policies that satisfy the needs of particular scenarios.
Current status	Initial complete versions of Datacentre Networking and network service provider PoCs (as demoed in the SDN World Congress) are ready, also integrated with the Network Manager.
Expected date of completion	1-2 years after the project ends, depending on interest by customers and the time it takes to define the characteristics for such a product.
Time to market	2-3 years, depending on the target customer. Initial interest in RINA as a datacentre solution expressed by R&D branch of Salesforce (as a mid-term/long-term solution for their DC networking needs).
Further external collaboration	Partnerships with other partners wishing to exploit similar solutions could be evaluated, specially with the SDK and Management System core developers.
Cost to exploit	Cost to exploit would depend on the specific needs of each customer
Protection required	Base software protected by the licenses described in section 3
IPR issues	No issues foreseen

i2CAT has also applied for funding to the **Producte** program of the Catalan government. This program provides funding to carry out pre-productisation activities such as drafting business plan, perform demonstrations in relevant environments, gather requirements for a full-fledged product, etc. i2CAT has proposed to carry out the development of a RINA product based on the IRATI RINA implementation for Linux, positioning it as an SDN/Overlay Network Virtualisation Solution for the Data Centre, SD-WAN and/or VPN markets.

4.3.7. iMinds

There are two important routes towards exploitation of the results. On the one hand, iMinds is an independent research institute that is working closely with industry. The knowledge and IPR gained in this project will be exploited in future projects with industry, where industry will directly benefit from iMinds knowledge but industry may also take over some of the IPR for further commercialization. iMinds is also exploiting its knowledge by establishing spin-off companies. More information: www.iminds.be/en/entrepreneurship. In addition, the research is fully embedded in the different Flemish universities allowing a very efficient exploitation of knowledge by embedding this in the more advanced master courses in engineering and related high-quality PhD programs. In this specific project, the research group IBCN (Internet Based Communication Networks and Services), part of Ghent University, is involved. Apart from transferring knowledge gained in the project through integrating this knowledge in courses of scientific papers, iMinds is participating in the development activities. The software contributed by iMinds is an integral part of the Open Source PRISTINE prototype, which is used as the basis for master thesis projects and as hands-on material for lectures on RINA.

Exploitation entries

Table 30. Academic exploitation

Partner	Type [a]	Starting date [b]	Ending date [c]	Topics
iMinds	PhD	Q1 2013	Q4 2017	Routing aspects of the Recursive InternetNetwork Architectures

Partner	Type [a]	Starting date [b]	Ending date [c]	Topics
iMinds	MSc	Q4 2014	Q2-Q3 2015	Comparing RINA and TCP for latency-constrained applications.
iMinds	MSc	Q4 2015	Q2-Q3 2016	Optimizing a BitTorrent file transfer protocol

[a] Phd or MSc
[b] Expected starting date
[c] Expected ending date

Table 31. Exploitation entry

Exploitable results number	IMINDS-1: RINA Traffic Generator
Exploitation type	Academic, Research
Lead partner	iMinds
Other contributing partners	Nextworks
Type of exploitable result/output	Software
Core function of output	Generate RINA traffic according to well-defined statistical properties.
Target segment for application	Research and teaching activities.
Major benefits and impact	Enable RINA tseting, experimentation and performance measurement activities.
Current status	Under development
Expected date of completion	Prototype ready for research purposes for the experimentation phase of PRISTINE (Early 2016).
Time to market	N/A
Further external collaboration	Possible future research projects, under evaluation
Cost to exploit	N/A
Protection required	GEANT outward software license is in place.
IPR issues	Joint copyright iMinds and Nextworks, License in place.

4.3.8. IMT

IMT-TSP exploitation plan in the scope of PRISTINE concerns basically proposing a MSc/PhD lecture that will introduce RINA architecture to

the IMT-TSP students. IMT-TSP is also investigating the possibility to set up national research projects to develop RINA-based IoT platform. IMT-TSP intends also to publish PRISTINE research results in conferences and journals.

Table 32. Exploitation entry

Exploitable results number	TSP-IMT-1
Exploitable result name	MSc & PhD introductory RINA course
Exploitation type	Academic
Work package	WP3, WP4
Other contributing partners	
Type of exploitable result/output	Course lecture notes
Target segment for application	Academy
Major benefits and impact	Allow students to learn a new promising clean slate network architecture, integrating the course to one of our master programs or PhD programs.
Exploitation potential	3
Current status	Initial steps of the course preparation
Expected date of completion	2017
Time to market	N/A
Further external collaboration	None foreseen yet.
Cost to exploit	N/A
Protection required	No
IPR issues	None

Table 33. Exploitation entry

Exploitable results number	TSP-IMT-2
Exploitable result name	National Project set up tentative
Exploitation type	Research
Work package	All WPs
Other contributing partners	
Type of exploitable result/output	Advance on Research/development of RINA and exploration of the possibility of using RINA in sensor networks and IoT
Final output and its applicability	RINA-based IoT architecture: benefit of RINA naming and addressing strategies
Target segment for application	Academy/Industry
Major benefits and impact	Being a very resource-constrained environment, IoT can benefit from

	the flexibility of RINA architecture. In particular, naming and addressing strategies and security can be beneficial to the rising IoT architecture. Therefore, the impact of PRISTINE can be to provide efficient services in IoT for smart cities.
Exploitation potential	3
Current status	None
Expected date of completion	2017
Time to market	3-5 years
Further external collaboration	Industrial/academic partners (under evaluation)
Cost to exploit	Under evaluation
Protection required	None.
IPR issues	None

4.3.9. Nexedi

Nexedi is the largest European open source software publisher with 10 different software products and 10,000,000 lines of self developed code.

The overall objective of the dissemination and exploitation plan for Nexedi is to promote the services of its decentralized cloud subsidiary (VIFIB) and its Enteprise Free Software along with raising awareness of RINA and the PRISTINE project and its results among a target community, including: software developers, companies, government bodies in charge of industry and students.

Through the RINA project, Nexedi will be able to improve two of its software products: SlapOS and re6stnet. SlapOS will provide initial integration of IRATI/RINA. re6stnet will support a form of scalability inspired by the recursive design of RINA. without losing its resilient nature.

SlapOS RINA

All developments done by Nexedi are already based on SlapOS. SlapOS is a hyperconverged operating system based on GNU/Linux that supports nano-containers and recursive orchestration. It has been deployed for mission critical applications at Airbus, Mitsubishi, SANEF, Kyorin, etc. Its promise based design makes it resilient (unlike OpenStack). And its source based build approach solves kernel API mismatch problems that prevents any LXC based container systems (incl. Docker) to be stable.

As a result of PRISTINE project, RINA has become one of the standard protocols offered by SlapOS in addition to IPv6 and IPv4. Nexedi now provides:

- a standard SlapOS image with IRATI/RINA support
- a tutorial to orchestrate RINA services with SlapOS

VIFIB - Nexedi's fully owned decentralized cloud subsidiary - will launch at the end of the project a cloud testbed to all RINA based projects and increase the awareness of RINA. RINA support is implemented as an extension of re6st mesh network that is used at the core of SlapOS architecture.

VIFIB's RINA testbed can be used to:

- develop new code based on RINA and automate its deployment in a distributed environment (35 sites)
- use a RINA-enabled Web based Platform-as-a-Service (PaaS) to teach RINA to students

VIFIB's RINA testbed will hopefully lower the effort to learn and adopt RINA.

Supporting RINA is also a way for VIFIB to adopt a protocol that may eventually prove to be superior to IPv6. Supporting RINA is thus an insurance policy for VIFIB.

Table 34. Exploitation entry

Exploitable results number	* NEXEDI-1: SlapOS RINA base image
Exploitation type	Commercial
Target segment for application	Cloud computing and experimental deployment
Major benefits and impact	Provide deployment RINA support for Cloud applications. This results in the ability to work on advanced R&D outside a large company that primarily focuses on stockholders rather than on innovation or economic utility.
Current status	Development of initial release
Expected date of completion	2 to 5 years after initial release, based on progress of IRATI

Time to market	2 to 5 years after initial release, based on progress of IRATI
Further external collaboration	NXW consulting is required to support users
Cost to exploit	Under evaluation
Protection required	GPL/LGPL has our preference because it protects us the growing theft of staff and effort conducted by large companies which do not contribute to Free Software through non copyleft licenses
IPR issues	we use employment contracts that prevent theft of staff

Recursive re6st

Nexedi currently uses IPv6 across its worldwide infrastructure and has obtained access in China to a license to interconnect business applications without government interference. Thanks to re6stnet, Nexedi is able to provide resilient connectivity between business applications. Failure of a router, of BGP configuration or government filtering has virtually no effect on applications interconnected through re6stnet. However, the current model of re6stnet is not scalable and can be broken either through DPI or through intrusion. Solving those problems was the key reason for Nexedi to join the PRISTINE project with the distributed cloud use case as application use case.

Discussions with other project members as well as the influence of the recursive RINA design have led us to find a solution for the scalability problem in re6stnet. re6stnet is actually a tunnel mesh generator which is network protocol independent. We will first extend re6st to support a recursive random mesh approach so that re6st gains scalability.

Table 35. Exploitation entry

Exploitable results number	* NEXEDI-2: recursive re6stnet
Exploitation type	Commercial
Target segment for application	Application delivery networks
Major benefits and impact	Provide resilient Internet connectivity worldwide (including in China) for business applications. Ability to work on advanced R&D outside a large company that primarily focuses on stockholders

	rather than on innovation or economic utility
Current status	Commercial, but non scalable and no fair routing
Expected date of completion	1 year after end of project for scalability, 3 years after end of project for fair routing and 5 years after end of project for pure RINA implementation
Time to market	1 year after end of project
Further external collaboration	N/A
Cost to exploit	N/A
Protection required	GPL/LGPL has our preference because it protects us the growing theft of staff and effort conducted by large companies which do not contribute to Free Software through non copyleft licenses
IPR issues	we use employment contracts that prevent theft of staff

Further Research Projects

Current RINA support in SlapOS by VIFIB is a first step towards a worldwide commercial RINA network.

Currently, RINA support provided by IRATI has two issues that prevent providing such a fully commercial service:

- lack of dynamicity in configuration
- IRATI implementation stability

Some aspects of current implementation of RINA by IRATI prevent for example adding and removing nodes easily, or changing routing configuration on the fly. This is mainly an implementation problem. In our opinion, the use of RINA with SlapOS in a dynamic environment helps a lot revealing those issues. We believe that much work can be done in the direction of improving IRATI itself to support dynamicity.

IRATI implementation could also be more stable. It is normal for a young project like IRATI to be unstable. It is already extraordinary in our opinion that IRATI itself exists. We expect that much effort should be invested to solve stability issues in IRATI and in particular memory leaks

and race conditions that happen in certain cases when changing network configuration on the fly.

It is thus very important that IRATI progresses in the future. Nexedi will be happy to support IRATI's progress with SlapOS.

We did not solve the problem of resilience of re6st to DPI and routing protocol intrusions. This is still an open research question for Nexedi that has to be solved. We have a lot of hope to find a solution in recent "fair routing" approaches, possibly combined with ideas related to "proof of work". Solving this problem will require to extend re6st with an API that compares metrics provided by routing and metrics monitored by tunnels. We expect that through the comparison of both metrics, we can implement fair routing and anti-DPI protection.

4.3.10. Nextworks

Nextworks is in RINA R&D since 2010, and started active development of the RINA stack on LINUX during the IRATI project (Open IRATI stack, https://github.com/IRATI/stack/wiki).

The rationale for Nextworks interest in RINA lays on the potential to tackle a new approach to datacenter networking in the era of network slicing, virtualization, clean-slate architectures. Being among the proposers of RINA solutions in this area can generate a competitive advantage for Nextworks. In fact, the Nextworks R&D team is particularly active with major TLC vendors and international Network Operators and NRENs with a consolidated portfolio of consulting activities on advanced network design and 3rd party SDN/NFV software development, which can benefit of RINA research and results.

In fact, RINA architecture naturally allows for resources slicing, by stacking layers (DIFs) one on top of the other and/or one next to each other, and allocating limited resources to each layer. This eliminates the need of encapsulation protocols (GRE, VPNs tunnels), which add complexity, require specific software/hardware support and add overhead. VPN and virtual networks can be implemented in RINA without the need of extending the architecture with new protocols. All in all, RINA introduces reduced complexity and can lead to improved performance and easier management.

Nextworks team covered the role of key designer and implementer for the PRISTINE SDK, and has particularly focused on the RINA Plugin Interface (RPI) and the consolidation ofteh RINA stack at all levels, to extend the final prototype released by IRATI and allow better programmability and RINA policy deployment.

Nextworks strategy for exploiting the great amount of work behind these tangible PRISTINE foreground has been developed and is progressing along three major drivers:

- Producing high-impact and visibility through the contribution to the dissemination actions (papers, workshops and tutorial reported in this document)
- Participating to the standardization work (ISO and PSOC and more recently ESTSI NGO activities
- Leading the integration and mainteinance of code and infrastructure of OpenIRATI as open source via GitHub.
- Spinning out a lightweight RINA stack implementation (rlite) to be used in RINA router prototypes and network operator/data center use cases.

All these actions have aimed at building the Nextworks position as RINA expert and implementer in the international research and industrial community, which has been successfully accomplished with the numerous activities reported in this document.

Nextworks expects that RINA research can primarily impact the market of the small-medium size (regional) network operators and campus networks, as these actors are commonly more inclined to deploy innovative networking solutions in shorter terms. In this market niche, the role of Nextworks as an SME could be decisive to engineer custom, flexible and advanced solutions tailored to the customer needs. Nextworks expects to pursue RINA R&D with a 3-4 years prospect to turn into market products. Based on this, the outcomes from the PRISTINE project (PRISTINE SDK, RINA Management System, Integrated PoCs for PRISTINE usecases) represent a key starting point towards consolidated prototypes of RINA routers and potential commercial products. To implement this strategy, Nextworks has just started working on RINA stack optimizations, branching from the OpenIRATI stack to implement an open source lightweight implementation of the RINA architecture (rlite), aimed at stability and performance improvement of the RINA stack.

In addition, RINA know-how can generate further business impacts along two main directions:

- improved expertise of Nextworks consultants involved in the design of specific network and cloud solutions, which turns into an offer to our customers of highly experienced network and software architects capable of extremely new and innovative solution design
- new offer for specialized training and tutoring on network technologies and RINA to interested customers (e.g. network/cloud providers, vendors, etc.).

The possibility to realize this short-term PRISTINE exploitation strategy is further increased by some strategic partnerships Nextworks has been developing in 2016 with big consulting firms (info on partner not-disclosable) to specifically cover this area of speciailized training sessions.

Participation in PRISTINE is also increasing Nextworks visibility to the wider research community active on 5G and next generation networks. Here the dissemination and standardization activities of PRISTINE

Exploitation entries

Table 36. Exploitation entry

Exploitable results number	* PRISTINE-1: RINA Software Development Kit (SDK)
Exploitation type	Commercial
Target segment for application	Consulting activities and research
Major benefits and impact	NXW customers would benefit from a reference implementation kept up-to-date with the specifications. The same reference implementation would also be the base for consulting activities on innovative network management solutions.
Current status	First iteration prototype released
Expected date of completion	2 to 5 years additional development, proof of concept and adoption of architecture concepts.
Time to market	2 to 5 year timeline, including internal proof of concepts.
Further external collaboration	Given the size of the code-base and its readiness level, continuous integration,

	updates and debugging are required. NXW foresee that enlarging the user-base and enforcing the Open Source related activities are key steps.
Cost to exploit	Under evaluation
Protection required	Open source with a commercial-friendly license would be the right path once adoption starts widening. However, given the status of the current code, NXW prefers a defensive strategy (GPL/LGPL), that allows to keep track of third parties modifications.
IPR issues	None

Table 37. Exploitation entry

Exploitable results number	* PRISTINE-5: Integrated RINA PoC for the Distributed Cloud Use Case * PRISTINE-6: Integrated RINA PoC for the Datacenter Networking Use Case
Exploitation type	Commercial
Target segment for application	Small-medium sized DC and campus networks
Major benefits and impact	Customer would benefit from flexibility that RINA provides in terms of resource allocation, ease of network virtualization (DIF as a basic block), built-in QoS and security mechanisms.
Current status	Currently in development of primary PRISTINE assets and awaiting project PoC trials.
Expected date of completion	2 to 5 years additional development, proof of concept and adoption of architecture concepts in company's data centers.
Time to market	2 to 5 years
Further external collaboration	Under evaluation
Cost to exploit	Under evaluation
Protection required	The PoC packages are based on OpenIRATI, which is currently licensed with GPL/ LGPL. In the next 2-5 years, however, we expect to relicense the software with a more commercial-friendly license, in order to allow to build products based on the PoCs.
IPR issues	None

4.3.11. PNSol

Predictable Network Solutions (PNSol) is a technical consultancy that specialises in the performance of systems at scale. PNSol provides world-class analysis and diagnostic support to the Telecoms and Defence sectors. PNSol looks forward to being able to exploit the RINA expertise it has gained in the project as RINA begins to be deployed by industry players.

PNSol only joined the project for the last 10 months. During this time it contributed to the design of the key management system and assisted in with the incorporation of its existing QTAMux IP into the RINA developments. This IP enables systems to deliver predictable loss and delay characteristics while under saturation. This IP is especially effective in a RINA context because RINA passes the information necessary to correctly configure the QTAMux component by default, which is not the case in current IP-based networks. This deficiency in IP-based networks has been an obstacle to PNSol in exploiting this particular intellectual property up to now.

Table 38. Exploitation entry 1

Exploitable results number	PNSol-1
Exploitable result name	Resilient Reliable Networking over Existing Interconnects
Exploitation type	Commercial
Work package	WP3
Type of exploitable result/output	Software
Target segment for application	Service Providers (both traditional and emerging)
Major benefits and impact	Existing low-cost networking solutions suffer from failures and variability in performance. Combining two or more such bearers could result in an overall system with greater resilience and more consistent performance. RINA provides a simple mechanism for doing such combining that includes resilience, management, event logging and security. Building on the work PNSol has done on the QTAMux in WP3 provides a baseline for delivering the more consistent performance that is desired. The impact of this will be to introduce

	a new class of product into the business broadband market.
Exploitation potential	2
Current status	Under discussion
Time to market	2-5 years
Further external collaboration	Potential follow-up H2020 submission
Cost to exploit	Under evaluation
Protection required	To be defined: the combination of RINA with previous PNSol IP opens up possibilities for creating patents that need to b explored more fully.
IPR issues	None.

4.3.12. TID

As the R&D branch of Telefonica, TID has been using and will continue to use its privileged communication path with network operations and business units to identify where and how the opportunities RINA offers can be considered for integration in its network. Though the very nature of the RINA proposal makes it difficult to consolidate it in the extremely cautious environment of network operations, there are clear opportunities to start building the case for a clean-slate approach to network architecture. The advent of the 5G initiatives is reopening the discussions about network evolution in network service providers, well beyond the "all-IP" goal that was the objective during the deployment of LTE infrastructures.

This is specially applicable to what relates to the use case TID is focused on: the support to NFV deployment and operation. In this particular aspect, TID will be able to demonstrate to the Telefonica Group how the results of PRISTINE can be applied in the design and deployment of its future vPoPs (virtualized Points of Presence), and to incorporate some results even in its current commercial networks. TID will rely on the availability of a demonstrator for the application of RINA to NFV, aiming at building a proof of concept according to the NFV PoC Framework (http://www.etsi.org/technologies-clusters/technologies/nfv/nfv-poc).

In what relates to the 5G environment, we are preparing a couple of lines of action based on the need of new protocols and architectures to achieve the 5G goals. One is based on running the above mentioned NFV demonstrator in the framework of 5TONIC (http://www.5tonic.org/), the 5G testbed Telefonica is deploying. The second is about incorporating the

RINA principles in the several proposals of the coming Second Phase of the European 5G initiative, the 5G PPP, particularly in those considering the evolution of Software Networks.

This 5G demonstrators and developments will be used for showcasing RINA within the Telefonica Group, as well as among the NFV community at large, continuing the current project efforts in workshops like the one held in The Hague in October 2016, within the SDN World Congress. We will continue pursing the goal of make this PRISTINE NFV demonstrators suitable to be applied to the technology showcases of the UNICA infrastructure (http://saladeprensa.telefonica.com/documentos/UNICA__20140224.pdf), the Telefonica telco cloud that has started its deployment during this year.

4.3.13. TRT

TRT (UK) is a provider of innovation and technology to the rest of the Thales group of companies. It is a centre of excellence for a variety of advanced technologies, which it develops for the use of the businesses and operating companies of the Group (Space, Security, Avionics, Transport, etc.).

TRT (UK) involvement in PRISTINE is mainly focused on security aspects in WP4. There has been special attention on the security functions and controls that can be exploited. Below we give the outline of an exploitable result, which have arisen to date. Detailed information on the results is given in the appropriate deliverables (D4.2 and D4.3).

Multi-Level Security (MLS) refers to access control mechanisms for protecting data or “objects” that can be classified at various sensitivity levels, from processes or “subjects” who may be cleared at various levels of trust. However, to make an MLS system practical it is generally necessary to allow for at least some capability to send data from a high system to a low system, e.g. to allow higher cleared users to send emails to lower cleared users. This capability cannot be achieved using SDU protection and needs to be carefully controlled to prevent accidental or deliberate release of sensitive information by users or malicious code. This exploitable result integrates the functionality of a Boundary Protection Component (BPC) into a RINA-based network. The RINA BPC is used to control flows of data between security levels, to ensure that data transferred

from the high system is actually at a suitable classification level for the low system. As RINA can sit and operate on top of any networking environment depending on the support of an appropriate shim DIF, the MLS solution can be used as an overlay RINA-based service function over any networking technology.

Table 39. Exploitation entry

Exploitable results number	PRISTINE-8: Multi-Level Security
Exploitation type	Commercial
Target segment for application	Network and Service Providers - There are many initiatives and application areas in various domains that require MLS solutions in order to provide easy sanitization and secure data sharing on a common infrastructure. These application areas includes data sharing in protecting Critical National Infrastructure (CNI), in multi-agency, multi-national coalition working environment and in business-to-business settings.
Major benefits and impact	Resilient, secure and highly-available networking is paramount to Thales and other organisations. MLS enables RINA to provide programmable secure networking for data sharing between systems and applications at different classifications. It allows cross-domain secure information sharing across multi-domain environments.
Current status	TRL-2/3. Designed, specified and implemented for Proof of Concept (PoC)
Expected date of completion	A laboratory component is available for PoC.
Time to market	2-5 years, needs further development, verification, and Engineering design. **Strategy:** The TRT-UK exploitation strategy for RINA's MLS solution can be explained into the following tracks: • To take the solution to the initial gate of Thales-UK R&T Management in order to further advance the solution to de-risking and maturation phase

	• Promote the use of the RINA concepts and technologies to open up new avenues of business in the Thales Group. • To take the solution to the main gate of Thales-UK R&T Management in order to transfer it to the engineering phase.
Further external collaboration	No.
Cost to exploit	To be specified.
Protection required	Yes. MLS solution in PRISTINE is dictated by policies and these policies and their security perimeters need to be highly protected.
IPR issues	Has been time-stamped and a patent application has been submitted. The licensing issue is under discussion internally.

4.3.14. UiO

The foundational lecture on Computer Networks taught at UiO, INF3190, contains a unit on problems with the current Internet and possible future directions for its evolution. How RINA addresses some of these basic problems is already being taught there, and PRISTINE results has been incorporated in this lecture unit.

We have already succeeded in a national research project called OCARINA, a 5-year project funded by the research council of Norway. The fund was very competitive, allocated to only around 60-100 top research projects in all academic fields in Norway. The project has been just started, building upon research results produced by PRISTINE.

Further planned exploitation at UiO includes writing further national project proposals that can propose research based on the Simulator and the SDK.

Table 40. Exploitation entry

Exploitable results label	UiO-1
Exploitable result name	MSc course
Exploitation type	Academic
Type of exploitable result/output	MSc course material
Target segment for application	Academy

Majors benefits and impact	Teaching students (future ICT professionals) the current state in the Internet and networking, and possible future directions with an introduction to RINA and
Current status	It is being taught.
Expected date of completion	Started from 2016
Time to market	N/A
Further external collaboration	-
Cost to exploit	N/A
Protection required	No
IPR issues	None

Table 41. Exploitation entry

Exploitable results number	For a nationally-granted project: * PRISTINE-1: RINA Software Development Kit (SDK) * PRISTINE-2: RINA Simulator
Exploitation type	Academic
Target segment for application	Academy
Major benefits and impact	It enables the exploitation of PRISTINE results, and enhancing its developed basic functionalities in the SDK and the simulator. Conducting research which can lead to better and safer networking.
Current status	A national research proposal based on RINA was accepted by the research council of Norway. An other proposal is being written at the moment.
Expected date of completion	September 2021.
Further external collaboration	It provides the opportunity to collaborate with other external research centers.
Cost to exploit	N/A
Protection required	No
IPR issues	None

4.3.15. WIT-TSSG

The overall objective of the dissemination and exploitation plan for the TSSG is to promote the research activities for the institute along with raising awareness of RINA and the PRISTINE project and its results

among a target community, including: researchers, software developers, companies, standardisation organisations, students and end-users.

Teaching

There are fellowship schemes in operation at the Waterford Institute of Technology (TSSG) which offer opportunities for suitably qualified women and men to pursue a Masters or Doctorate level postgraduate degree by research. During the period of the PRISTINE project, the TSSG opened up this offer in the technological area of RINA, and the policy-based configuration and autonomous operation of the DIF management system.

The institute also runs a one year taught Masters programme, and it is envisaged that as the project runs in the academic year of 2015-2016, there will be a new dissertation which relates to the research themes of PRISTINE.

Table 42. PhD and/or MSc theses

Type [a]	Starting date [b]	Ending date [c]	Topics
Phd	01/09/14	31/08/2017	Investigating Self-orchestration behaviour in Recursive Network Architectures
MSc	01/10/2014	30/09/2015	Load balancing applications using RINA

[a] Phd or MSc
[b] Expected starting date
[c] Expected ending date

There is one member of the TSSG team that is a full time lecturer at the Waterford Institute of Technology and he will work on full-time academic courses where several distinct modules will have their content created or updated, based on involvement in the PRISTINE project.

- BSc in Applied Computing.
  - Internetworking
  - Distributed Systems
- BSc in Multimedia.

- Network Systems and Concepts

- BSc in Information Technology
  - Network Fundamentals
  - Internetworking
  - Network Technologies
  - Cloud Infrastructure
- MSc in Computing (Communications Software).
  - Communications Infrastructure & Security
  - Communications Services Management

Table 43. WIT-TSSG Teaching Exploitation entry

Exploitable results	WIT-TSSG-01
Exploitation type	Academic
Target segment for application	Education
Major benefits and Impact	New networking teaching material at the Post-graduate and under-graduate levels. New graduates will leave the academic institute with a new perspective on networking and will bring to their new employers a revived sense of what a new network can bring to Internet applications. This has the potential to delivery an innovation cycle in networking which hasn't been seen in 30 years.
Current status	Post-graduate programmes have started, and an investigation is on going in regards to including PRISTINE/ RINA related material into undergraduate programmes.
Expected date of completion	Q3 2016
Time to market	Q1 2017
Further external collaboration	It is not foreseen that external collaboration will be needed to initiate this teaching material, however it may be needed when it comes to sharing out and disseminating the material.
Cost to exploit	As this material will be infused into the Post-graduate and under-graduate programmes, the cost will be bore internally to the college.
Protection required	Copyright
IPR issues	No

Scientific Communities - Workshops

Publication is an important part of TSSG research. The peer review process safeguards the credibility and scholarly merit of our work, and publication ensures that our results, findings and conclusions are disseminated to the research community.

Therefore the TSSG will continue to plan to target high impact journals such as the Journal on Network and Systems Management (JNSM), and IEEE Transactions on Network and Service Management (TNSM), and conferences such as IFIP / IEEE Integrated Network Management (IM), IEEE Conference on Network and Service Management (CNSM), IEEE Network Operations and Management Symposium (NOMS) and IEEE Conference on Network Softwarization (NetSoft).

The main objective for the TSSG will be to promote the work on configuration management, performance management & security management in RINA. We also want to raise awareness among the RINA research and wider communities of the possibilities to contribute towards this research work.

Table 44. WIT-TSSG Scientific Exploitation entry

Exploitable results	WIT-TSSG-02
Exploitation type	Research
Target segment for application	Scientific Community
Major benefits and Impact	A number of scientific publications based on PRISTINE work, where high-level data sets are made available through appropriate archives, and tools are developed for the advanced research of RINA. This activity is expected to add value to existing activities on European and international levels, and enhance and broaden research partnerships. It will help to increase the innovation, harmonisation and technological develop of RINA, which will increase its possible take up by industrial research centres.
Current status	4 research papers have been presented and 1 further paper is being drafted.
Expected date of completion	Q4 2016
Time to market	It will take up to Q2 2017 to fully disseminate the research finds and material.

Further external collaboration	Further external collaboration is expected.
Cost to exploit	While there is a disseminate budget available with in the PRISTINE project, it is foreseen that additional funding will need to be raised to help continue the dissemination of the research results into 2017 and beyond.
Protection required	Copyright
IPR issues	None

Commercial exploitation

The evolution of the PRISTINE project has shown the commerical potential of the projects outputs. The TSSG had a key part to play in organising and coordinating the delivery of the final PRISTINE workshop at the SDN World Congress, and it was here at an industrial lead conference that RINA, and the outputs of PRISTINE have shown themselves to be useful to the future 5G market.

The TSSG is quite active in start-up companies, and in 2014 had a spin-out company acquired by Red Hat. Based on initial results of PRISTINE the TSSG has initial investigations underway on the possible market opportunities for the RINA DMS in the application area of mobile edge computing (MEC), however it is at a very early stage and additional market research needs to be undertaken. Towards this end the TSSG plan to actively participate and present in commercially focused industrial expos in 2017.

The TSSG have also participated in standardisation activities, most noteably contributing to the ETSI Next Generation Protocol (NGP) ISG during 2016.

Table 45. WIT-TSSG Commercial Exploitation entry

Exploitable results	PRISTINE-1 : RINA Software Development Kit (SDK), PRISTINE-3: Management System for RINA networks
Exploitation type	Commercial
Target segment for application	Orchestration system vendors in the communications network space and enterprise data centre network operation space.
Major benefits and Impact	Benefit from a reference implementation kept up-to-date with the RINA specifications. The same reference implementation would also be the base for consulting activities towards these vendors. There is the potential for

	a technology being developed here to be either licensed by a tier 1 orchestration systems vendor, and the investigation of a start-up company taking this product to market will be investigated.
Current status	PRISTINE phase II software base released (M30 of PRISTINE)
Expected date of completion	Q3 2016
Time to market	Initial investigation on this topic appears to point towards Q4 of 2017.
Further external collaboration	This product will require external collaboration especially in the SDN/NFV market place.
Cost to exploit	There will be a need to raise new funding for the exploitation of this product.
Protection required	Patents
IPR issues	None to date

Further Research Projects

As coordinators of the project, the TSSG have and will continue to actively participate in the activities organised at the EC programme level relating to the ICT Next Generation Internet area. The TSSG will provide input towards common activities and gather feedback (e.g. from NGI clusters and coordination groups), offer advice & guidance and digest information relating to EC ICT programme implementation, standards, policy and regulatory activities. Such activities will include participation in concertation meetings and the European Conference on Networks and Communications.

Given that the TSSG lead the PRISTINE project, and and have participated in research projects such as 4WARD, AUTOI, PERIMETER, and the 5G PPP project CogNet the TSSG can leverage these projects and its connections to widen the TSSG's industrial collaboration of PRISTINE research topics and possible follow on research projects and industrial technology transfer.

5. Evaluation of Key Performance Indicators

PRISTINE's Description of Work (DoW) document describes a number of metrics which capture the expectations on the project's dissemination, standardisation and exploitation activities. These metrics are summarised in the following table.

Table 46. PRISTINE SDK evaluation metrics, as presented in the "Description of Work"

KPI No	Metric	Description
KPI 6	Expressions of interest in the usage of the PRISTINE SDK, by organisations external to the project	This indicator will showcase the potential impact that the SDK developed by PRISTINE can achieve. Since the full SDK will not be available until the final stages of the project, it is difficult that a lot of organisations external to the project can actually use it. However the consortium will promote the SDK and allow limited access to a number of interested parties, starting by the members of the PRISTINE External Advisory Board. The PRISTINE consortium expects to involve at least **3 academic and 2 industrial organisations** (including SMEs) in the usage of the SDK during the project lifetime.
KPI 7	Number and relevance of publications disseminating PRISTINE's experimental research	Regardless of the outcome of the project, the results will be published in well-known journals. This indicator will measure the success of PRISTINE's academic publications. The PRISTINE consortium will aim for a minimum of **15 refereed academic papers and 2 journal papers** during the project lifetime.
KPI 8	Number of academic and industrial organisations attending the workshop celebrated at the end of the project	It will be an indicator of the interest that the PRISTINE project has been able to generate during its lifetime. It is expected that **at least 60 attendees from 20 different organisations (from universities, SMEs and the ICT industry) will attend PRISTINE workshops**.
KPI 9	Interest of the consortium members and External Advisory Board partners in engaging in further RINA research	This could be quantified by the number of RINA-related research and innovation activities the consortium and the EAB members will undertake due to their participation in PRISTINE; including joint

KPI No	Metric	Description
		publications, workshops and follow-up research projects.
KPI 10	Contributions to standard bodies other than PSOC	Number and quality of the contributions to existing SDOs such as the IETF or ETSI. **The PRISTINE consortium will aim for a minimum of 4 contributions towards SDO's during the project lifetime.**
KPI 11	Partners exploitation interests	Number and scope of the exploitation activities related to the project results performed by the project partners or the members of the External Advisory Board. **It is expected that each partner performs at least one exploitation activity**

5.1. KPI 6: SDK usage outside of PRISTINE

Although this is a KPI for the SDK, D2.5 reported that this KPI would be measured at the end of the project. To the best of PRISTINE partners knowledge, the following academic organisations have shown interest on using the SDK or have actually used it:

- **University of Amsterdam** (Netherlands, Master students)
- **Instituto Politecnico Nacional** (Mexico, PhD students)
- **University of Zaragoza** (Spain, Industrial doctorate H2020 proposal)
- **Universidade Federal do Pernambuco** (Brazil, PhD students)

Regarding industrial organisations, the following ones have expressed their willingness to experiment with the SDK:

- **Salesforce**. Salesforce is a global Enterprise Cloud provider, running multiple DCs. One of the Salesforce Network Architects (Mr. Rick Casarez) got interested in RINA after attending the "*Recursive Congestion Control*" presentation delivered at the IETF meeting in Buenos Aires (2016). He then contacted the project and a meeting was organized with PRISTINE project representatives during the IETF meeting in Berlin (2016). Mr. Casarez expressed his interest on RINA and explained he was eager to work with the IRATI open source community and their vendors to accelerate the development of RINA-based products so that his team could adopt them in their DCs.

- **Interoute**. EAB member Adam Chappell has monitored the results of PRISTINE, and is interested on setting up an internal RINA demonstrator using the SDK and demonstrator tools.

5.2. KPI 7: Publications

The following table summarises the publications in conferences and journals by members of the PRISTINE consortium. The conferences target has been already achieved, pending still 3 articles under review. Up to know no publications in journals have been carried out yet, although 3 will be submitted during Q4 2016 and Q1 2017; therefore still having some possibilities to achieve the goal for scientific journal publications. Last but not least, PRISTINE has published an IEEE SDN Newsletter - which has a good impact within the SDN R&D community - and has submitted another one which is still under review.

Table 47. Publications in conferences, workshops, journals and other

	Conferences & workshops	Journals	Other
Accepted	17	0	1
Rejected	8	2	0
Under preparation/ review	3	3	1

5.3. KPI 8: Attendance to PRISTINE workshops

PRISTINE modified a bit its initial strategy of trying to organise a single workshop that attracted the interests of both academia and industry at the same time - since the type of content and workshop structure needs to be different for these types of audiences - and instead carried out two workshops (more industry-oriented) and two tutorials (more academia-oriented) during the second half of the project.

- **PRISTINE workshop at SDN & OpenFlow world congress 2016**. The last workshop of PRISTINE was a completely industry-oriented event run in the most important SDN conference of the year. It featured a selection of demos showing the project results and discussed implications of products and services exploiting PRISTINE's work. The workshop was attended by around 40 delegates of companies such

as Canonical, Google, Level 3, Huawei, KPN, EE, CPlane Networks, Symantec or RAD COM.

- **Evolution and revolution of the Internet workshop at Pisa Internet Festival 2015**. The workshop discussed with invited experts from leading industries and researchers how Software Defined Networking, Network Function Virtualization and RINA can change and enhance the networks and the services for the Internet. The event was attended by an audience of about 50 people, composed of PhD students, researchers and industry professionals. It was a balanced audience, with a 60%-40% split between academia and industry.
- **RINASim introduction at the third OMNeT community summit(2016)**. After a successful RINASim presentation at 3rd OMNeT Community Summit, the OMNeT community decided that the RIMASim framework is not only interesting but also worthy of further dissemination. Hence, RINASim was accepted as the official OMNeT++ feature project.
- **PRISTINE tutorial at EUCNC 2016**. The goal of the tutorial was to provide the mostly academic audience with an introduction to the concepts, motivation and state of the art of RINA (showing the latest PRISTINE results). The audience was low due (5-10 attendees during the session) to the high number of parallel workshops and tutorials taking place at the same time.

5.4. KPI 9: Further RINA research

PRISTINE partners and EAB members have showed the following interests in engaging in further RINA research.

- *Ericsson*, *Telefonica*, *Nextworks*, *i2CAT*, *iMinds* and *Boston University* have obtained an H2020 research grant to continue working on RINA and the IRATI open source implementation within the **ARCFIRE project** (Large Scale RINA benchmark on FIRE+). *Interoute* is a member of ARCFIRE's advisory board.
- *iMinds* has obtained a research grant from the Flemish government to study the application of RINA in the Internet of Things (IoT) domain with the *University of Leuven*, within the **RINAISense project**.
- *University of Oslo* has obtained a research grant from the Norwegian government to continue the research of congestion control and routing

in RINA within the **OCARINA project**. *i2CAT* and *Boston Univeristy* are advisors of the project, and will be hosting PhD students from University of Oslo working in the project.

- PRISTINE EAB member *Predictable Network Solutions* has joined the PRISTINE project as a full partner, taking the tasks of Juniper (which left the project).

5.5. KPI 10: Contributions to SDOs

PRISTINE partners have made *6 contributions* to the following SDOs:

- **ISO SC6 WG7 (2 contributions)**. PRISTINE members have managed to get the approval of two "New Project" proposals to standardise different aspects of RINA: "*Network Architecture*" and "*Protocols*".
- **ETSI ISG NGP (3 contributions)**. In addition to the multiple contributions presenting and explaining the RINA concepts in the first three face to face NGP meetings, PRISTINE members have contributed to the three following work items:
  - *ISG NGP White Paper*
  - ISG NGP Group Specification 1 (GS 001): *Next Generation Protocols: Scenario Definitions*
  - ISG NGP Work Item 3: *Next Generation Network Architectures* (not yet public)
- **IRTF (1 contribution)**. Results on recursive congestion control performed in PRISTINE's WP3 were presented and discussed during the IRTF/IETF meeting in Buenos Aires during April 2016.

5.6. KPI 11: Partners exploitation interests

The main exploitation actions that have / are being carried out by PRISTINE partners are summarised in the following table.

Table 48. PRISTINE SDK evaluation metrics, as presented in the "Description of Work"

Partner	Main exploitation actions
Atos	Evaluating the applicability and impact of PRISTINE solutions for datacentre networking and distributed clouds in their product lines targeting the Cloud computing markets.
BISDN	Explore the feasibility to design and develop two different solutions: i) hardware accelerated RINA routers for better performance, targeting the

Partner	Main exploitation actions
	data-centre space; and ii) a more manageable and robust ISP access network transport solution.
CREATE-NET	Academic exploitation via M.Sc. courses, seminars and PhD theses. CREATE-NET has already performed a 4-hours RINA seminar and has also been involved in a RINA-based MS.C thesis.
Ericsson	Investigate impact of RINA on product lines, use RINA to create industry awareness on clean-slate network management practices and continue involvement on open-source RINA activities. Ericsson is already performing some of these tasks as coordinating partner of H2020 ARCFIRE.
FIT-BUT	Academic exploitation via Ph.D. theses (one has already been defended, the other one is ongoing). Development of new Ph.D-level course with outputs from PRISTINE (to be taught in the 2017-2018 academic year). Exploitation of RINASim - already been recognised as one of the official OMNeT++ frameworks.
i2CAT	Engagement on further research projects to continue pursing RINA-based R&D (i2CAT is technical lead of ARCFIRE), and work to transfer PRISTINE results to the market (i2CAT has applied for funding from the Catalan government to carry out pre-commercial work on a potential overlay virtual networking product based on the IRATI implementation).
iMinds	Academic exploitation via M.Sc. theses (two completed) and Ph.D. thesis (one ongoing). Further RINA research activities via H2020 ARCFIRE and RINAISense. Exploitation of open source RINA traffic generation framework.
IMT	Academic exploitation via development of MSc and/or PhD introductory RINA course (under development). Research exploitation trying to get national funding for RINA-based IoT research project.
Nexedi	IRATI RINA implementation has been integrated in the standard image of SlapOS (the software powering Nexedi's distributed cloud solutions), as a Proof of Concept (PoC). Nexedi will analyse the effort required to provide deployment RINA support for Cloud applications and also redesign re6tnet to fully support recursiveness. Nexedi will integrate further updates of IRATI within the SlapOS image.
Nextworks	Spin-out of open source lightweigth RINA implementation (rlite) targeting router prototypes and resource-constrained environments. Nextworks will also setup and maintain PoCs up to date, targeting potential customers in the datacentre and ISP space.
PNSol	Exploitation of QTAMux-RINA integration to introduce a new class of product in the business broadband market, providing better resilience and more consistent performance. Engagement in further R&D products is also considered.
TID	Setup of internal PoC to demonstrate the Telefonica Group how the results of PRISTINE can be applied in the design & development of future vPoPs (virtualised PoPs), building on the work of RINA NFV support. Explore RINA's applicability to the design of converged network operators within H2020 ARCFIRE. Incorporate RINA principles in 5G PPP call 2 proposals.

Partner	Main exploitation actions
Thales	Exploit RINA-based Multi-Level Security solution prototyped in PRISTINE as an overlay service-function over any networking technology. In that regards a patent application has already been submitted.
UiO	Incorporate PRISTINE results at the foundational lecture taught on Computer Networks at UiO (done). Course material for introducing RINA as a possible future direction for networking in MS.C courses (taught since 2016). Continue RINA R&D activities on congestion control and routing leveraging IRATI implementation and RINASim (OCARINA project starting October 2016).
WIT-TSSG	Academic exploitation via ongoing Ph.D thesis and completed MS.C thesis. Development of course material for BSs, MSc and PhD level courses, to be taught in 2017. Analyse commercialisation potential of exploitation of PRISTINE results, getting in conversations with Orchestration system vendors in the communications network space and enterprise data centre network operation space.

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