ICT SHOK Future Internet Programme (ICT SHOK FI)

Programme Plan

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Abstract

Several present bottlenecks constrict the future progress of the Internet: unwanted traffic, choking of the routing system, mobility and multi-homing, compensation and congestion, privacy and attribution, and trust and reputation. We believe that these deficiencies and bottlenecks are already limiting the potential utility of the Internet by making certain kinds of applications infeasible or unattractive. If so, a vast potential market at present is unserved. Therefore, the core theme of the Future Internet (FI) programme is to remove the obstacles from the path towards a smooth and efficient platform that also offers an efficient and transparent market for new innovations and applications - in short, towards network as a free market.

This programme proposal represents our first steps towards this long-term goal. It discusses the work to be carried out during the first four years of the FI programme, and gives a more detailed account of the first two years. In the first phase, the Future Internet programme focuses on three main themes, namely the health of the Internet routing system, exploration of ways to improve the quality of end-to-end connectivity over the Internet, and investigation of new ways of information storage and delivery in the Future Internet.

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1. Introduction

Two major interlinked changes in the Internet are presently challenging its structure and reshaping its future: the move from the end-to-end principle towards a trust-to-trust principle and from inter-connecting nodes towards interconnecting information. Other main change drivers include connectivity, scalability and autonomous resilience.

Several present bottlenecks constrict the future progress of the Internet: unwanted traffic, choking of the routing system, mobility and multi-homing, compensation and congestion, privacy and attribution, and trust and reputation. The major challenges blocking its future development include information networking, energy consumption, changing usage patterns, and the impact of shifting bottlenecks.

We believe that these deficiencies and bottlenecks are already limiting the potential utility of the Internet by making certain kinds of applications infeasible or unattractive. If so, a vast potential market is at present unserved. Therefore, the core theme of the Future Internet programme is to remove the obstacles from the path towards a smooth and efficient platform that also offers an efficient and transparent market for new innovations and applications – in short, towards network as a free market.

This programme proposal represents our first steps towards this long-term goal. It discusses the work to be carried out during the first four years of the FI programme, and gives a more detailed account of the first two years. The budget has bee prepared for the first 12 months of operation with the intention that the programme may grow considerably in its second year. The budjet of the first year is about 6 Me and includes about 50 person years of research work.

2. Programme Objectives

Future Internet programme implements the mission given in the Future Internet Strategic Research Agenda: "To combine efforts of Finnish companies and academia to make a significant contribution towards developing the Future Internet technology and ecology as a platform for innovation, especially focusing on network and information governance and leveraging mobility as a key source of competitiveness and global added value". The programme plan describes activities in a handful of work packages for the next two years to address the key future challenges and problems identified in the SRA. The plan also outlines longer term actions to tackle the more fundamental challenges in the current Internet architecture.

While the detail planning focuses on the next two years, the programme is intended to form a long-term activity that will extend trough the entire duration of the programme. Therefore, we aim to update the plan every two years as we go along. It is also likely that other projects, some with more limited or short-term objectives, some focusing on a particularly challenging research theme or international collaboration, will emerge during the work of the programme as offshoots of this work.

The programme looks at solutions with a foreseeable deployment plan in next few years, as well as solutions that require more fundamental changes in the Internet architecture and can be seen as longer term research activities. The programme also applies different methodologies from theoretical analysis and simulation to concrete experimentations in realistic network environments. Further, the programme establishes a testbed that supports the programme researchers by providing basic services and operations for experimental investigation of different networking solutions. Finally, the programme actively interacts with the international standardization bodies, such as the IETF, and research activities in EU and US aiming to make impact on world-wide Future Internet research and development process.

In the first phase the Future Internet programme focuses on three main themes.

- The health of the Internet routing system has become a pressing concern among the international bodies that study and standardize the routing mechanisms. The Future Internet SRA document discusses the problem of relative choking of the routing system, with the legacy protocols having to perform in an increasingly complex environment. The programme investigates novel addressing and routing schemes that could be contributed to the international standardization bodies and eventually taken into use in the Future Internet.
- As a second main theme, the programme explores ways to improve the quality of end-to-end connectivity over the Internet. The SRA discusses the challenges related to energy efficiency, modelling and analysis of the communication performance and reliability, and resilience of the Internet connections. Moreover, the reachability of communication entities, both before a contact and during the communication is paramount; efficient and secure solutions need to be investigated, in particular with regards to new visions in mobility and the effect of challenged environments. The programme takes actions to tackle these problems in a network environment that is increasingly mobile and heterogeneous by its characteristics.
- The third main theme in the programme investigates new ways of information storage and delivery in the Future Internet. The programme challenges the traditional Internet information access methodology based on finding the information from known host addresses, seeking novel dissemination architecture for Internet information sharing and discovery.

The programme plan has also identified a number of issues that concern all of the themes presented above, and proposes a plan to ensure that these issues are consistently addressed by the individual work packages at different portions of the Internet architecture. It is also possible that some of these themes may later be elevated to full work packages. Another theme that will become increasingly critical as the work progresses is network management, and it too is a strong candidate for a new work package in a later update of this plan.

The Strategic Research Agenda will be maintained during the course of the programme, based on the developments in- and outside the programme. The SRA is reviewed roughly annually, and if necessary, the focus area director can appoint a group of people to revise the SRA to reflect the current understanding of the research environment.

The programme maintains a roadmap of the research topics that are divided into short-, medium- and long-term research. The roadmap describes the consortium's vision on when the programme topics are estimated to be deployed and in use. The focus area director assigns a responsible person for maintaining and revising the roadmap.

3. Programme Management

The management structures and procedures of the Future Internet programme have been designed on the basis of the principles defined in the ICT SHOK documentation. The consortium has refined these principles on the basis of the considerable experience of the consortium members from various kinds of national and international projects. In particular, the management models of EU framework projects have been used as a blueprint of the model adopted by us.

A major goal of the management model is to ensure transparent and efficient decision-making to maintain the focus and impact of the research, while not imposing a large overhead. The management model also recognizes the industry-led character of the programme: ultimately, the resources available to the work and how they are allocated to various activities depend on companies' commitment. Thus, those decisions are delegated to a steering board composed of the major industrial partners. This model was adopted already during programme preparation, and has shown to be effective. Those decisions that require unanimous decisions are done in the general assembly of all partners.

The daily management of the programme is handled by the focus area director and the academic coordinator. The focus area director, Mr. Reijo Juvonen from NSN, leads the work in the Future Internet programme, chairs both the steering board and the general assembly, is responsible of coordinating the SRA mainte-

nance and the Future Internet roadmapping work. The focus area director also represents the programme to Tivit Oy.

The academic coordinator is professor Jukka Manner from TKK (HIIT and Comnet). The academic partners are organized in a separate funding application. The academic coordinator is responsible for coordinating the administration of the academic partners in the programme, such as reporting to Tekes. Academic coordinator also facilitates SRA Director in coordinating the programme activities, managing programme deliverables, and arranging Steering Board meetings and other events.

The steering board consists of representatives of the major companies and research institutes participating in the Future Internet programme in ICT SHOK, in addition to the Tivit Oy CTO, the SRA director and the academic coordinator. The steering board approves the plans and supervises the work and reporting to Tivit Oy. The steering board meets roughly four times a year, and is called by the SRA director.

The general assembly consists of representatives from all partner organisations. Also Tivit Oy CTO, the SRA director and the academic coordinator attend its meetings. The general assembly decides on matters that require unanimous decisions, such as accepting the consortium agreement and its possible amendments. The general assembly is expected to meet once a year.

4. Work Packages

The work in Future Internet programme is divided into work packages with assigned objectives and assigned work package leaders. Work packages further split their work in well-defined activities with contributing partners and a responsible person to lead the activity execution. Work package leadership is primarily assigned to a participating organization, which appoints a person responsible for the leading. Steering board approves the work package leaders and reappoints the leaders if necessary. The work packages are as follows:

WP 0 Management and cross-WP topics

WP0: Management & Cross-issues

This work package includes the management and coordination work of the programme. Primarily this is the work done by the focus area director and the academic coordinator and their organisation. The work package also includes the research work done in the six cross-WP issues identified in **Figure 1** below.

WP 1 Routing scalability

WP1: Routing scalability

The complexity of the Internet routing system increases faster than the Internet itself is growing. A primary reason for this is that classic aggregation mechanisms – designed to increase routing scalability and hence to limit complexity – have undesired constraints for edge networks in terms of routing flexibility and network management, and thus oftentimes remain unused by edge network operators. This is in particular so for edge networks that multi-home with more than one Internet service providers. The shortfalls are exacerbated by an emerging need to support two addresses spaces during the transition from the exhausting IPv4 address space to the IPv6 address space.

The high level research question for this work package is the following: How would the routing system of the Future Internet servicing several billions of mobile users running real time applications look like? This question translates into multiple sub questions such as what are the routing objects and related addressing structures, how is the aggregation to be arranged, how are the routes created and propagated, what are the expected performance characteristics and what kind of policies ISPs and operators would like to impose to facilitate diversity of commercial relationships and business models, between their peers and customers, and should the routing system offer means for services other than simple basic packet routing and forwarding.

The short and medium term activities of this work package are reflecting and impacting the work in routing areas of the IETF and IRTF. Understanding the operating policies and practical operational aspects of routing, such as firewall and routing/addressing scheme interactions is essential when assessing the feasibility of the alternative approaches.

The long term objectives of the work package include development of new routing schemes such as compact routing, meta routing and routing approaches at the link layer (e.g. Ethernet routing). Management support of unwanted traffic and mobility are closely related to these new developments.

WP 2 End-to-end connectivity

WP2: End-to-end connectivity

WP 2 concentrates on end-to-end IP connectivity of networking hosts, either mobile or stationary. True end-to-end IP communication is challenged in multiple ways in the present Internet. Some of these issues originate from network providers' and enterprises' way of deploying their networks with a number of intermediating nodes that effectively create isolated islands of networks with partial and asymmetric connectivity. These deployments are typically intentional due network resources and security reason or because of enforcing certain business models. There are no definite

models or guidelines how to deploy networks that make it extremely challenging for the end hosts to communicate without disruption or deploy new protocols within these heterogeneous network environments. A number of ad-hoc and point solutions have been developed to circumvent some of the pressing challenges, such as those for mobility at various forms and layers, multi-homing, NAT and firewall traversal. Unfortunately, the trend seems to be solving the same issues every time a new protocol or deployment scenario gets developed. Often these solutions extend or modify some existing protocol, rather than trying to solve the actual origin of the problem.

The activities in this work package have been categorized into two main themes: IP-based transport and mobility. Within these two themes the main research interest is focused into three areas. The first area of activity is the energy efficiency and the energy awareness of the future Internet communication. The main interest is in wireless IP-based communication, which also ties all activities within this area closely to mobility. The second area of activity is the IP communication in a challenged network environment that often arises at the edges of various networks. The third and the last area of the activity is the future developments in Internet transports. This activity does not only concern specific protocols but also addresses the general design of communication stacks, mobility and rethinking the Internet resource management.

WP 3 Information networking

WP3: Information networking

The goal is to design and implement an architecture for an information dissemination system which meets the demands of information networking in the Future Internet. The work package has three fundamental issues to address: *Storage*, *dissemination*, and *accessing* of information. Securing access to and retrieval of media adequately needs to be addressed across all three areas and is captured as a fourth major task.

Accessing information stored on the current Internet mostly follows a very simple paradigm. A content provider creates the information and stores it on a web server. Users somehow need to learn the address of the web server and the exact file name of the information stored on the server in order to access the information. Users might get the address through a search, advertising, or a bookmark in the case where the user has visited the web site earlier.

There is no actual dissemination of information, beyond the simple unicast transmission from the server to the user. And, for practical reasons, content access is virtually always invoked by the clients ("pull"), even for notification services such as RSS feeds. Active content dissemination is mostly found as replication mechanisms to mirror servers inside service provider infrastructures (Content Distribution Networks, CDNs). Information networking aims at changing this server-centric paradigm into an information-centric view. Content providers

publish their information into the network and users access information by specifying what information they are interested in; not by connecting to a specific host on the Internet and requesting a particular file stored on that host.

Key challenges in this information-centric view are: *How persistent is information and how is persistence maintained, how is stored information managed in the network, how do users discover what is available, and wow do users retrieve the information they are interested in?*

WP 4 Testbed

WP4: Testbed

Experimentally driven future Internet research requires validation of the results. The validation needs to be done in an environment that is sufficiently large and real-world-like to give confidence in the results. For this purpose, a testbed with sufficient geographic coverage is needed. WP4 contributes to the programme by providing the testbed design and infrastructure. WP4 supports programme researchers by providing basic services and operations in the experimental infrastructure. A powerful network for testing is established with the basic services. The tests are coordinated. The network is operated and finally closed. The procedures and usage are reported. The testbed design is flexible which allows testing of different architectural aspects of the ICT SHOK vision.

To support truly disruptive research, the testbed allows experimentation at and below the network layer (L3). For example, it is possible to experiment with different kinds of framing at the data-link layer (L2) and coding at the physical layer (L1). To accomplish this, access to clear channel (dark fiber or lambda) is needed. The testbed allows the use of high bandwidths which are either not available or not commercially feasible in general purpose Internet. It is also important that the testbed allows the conduct of experiments that would be dangerous or illegal in the Internet, such as studying DoS attacks or the spreading of worms and other types of malware.

Special attention is given also to the access networks. Partners are encouraged to provide various different types of access in their tests. Broadband wireless access (Wi-Fi, WiMAX etc.) is obviously interesting. Also cellular access (3G, 3.5G etc.) is covered. The testbed supports testing in a mixed environment where a part of the test infrastructure is able to communicate to the general Internet. This provides a possibility to test services in near production class setups. Also, in many cases, tunnelling over the Internet can be used. Connection to the general Internet also allows early field trials and concept tests. Support for a continuum from basic and applied research to product development and experiments with real users (e.g. LivingLabs) is provided. Clean-slate experiments and tests (e.g., non-IP protocols, routing and naming architectures) are also supported using L1 or L2

connectivity and/or new types of access networks. Federation means the peering between testbeds under different management. Federation of testbeds is needed to achieve sufficient scale, geographic scope and diversity for large experiments. Possibilities to federate the testbed with other testbeds (e.g. under FIRE) will be studied.

WP 5 Dissemination and international collaboration

The objective of WP 5 is to facilitate the wide adoption of the results of the programme by the world-wide Internet research and industrial community. This is critical to the success of the programme through ensuring that developer and user communities external to the programme get recruited to share the load of the work, and provide their experience on the results. The work includes activities such as organizing public events, promoting the public visibility of the programme and its results, facilitating the build-up of competences for the programme through co-operation with suitable educational programmes (M.Sc., doctoral) and research institutions, facilitating coordination and support collaboration between the ICT SHOK programme and other Future Internet related research projects, and create and maintain close links with key international partners in academia and industry. Furthermore, a key part of this work is the creating and maintenance of presence with international standardization organizations, in particular with the IETF, through active dissemination of our results and ideas.

A number of issues have been identified that need to be considered in different work packages; these are called cross-workpackage topics. A responsible person is appointed to take care that the issue is handled in appropriate way during programme planning and execution according to plan that is defined at a later phase. Figure 1 presents an overview of the four technical workpackages and six cross-workpackage issues. The cross-workpackage issues are related to all work items, at some level or another. The cross-workpackage issues are studied as part of WP0.

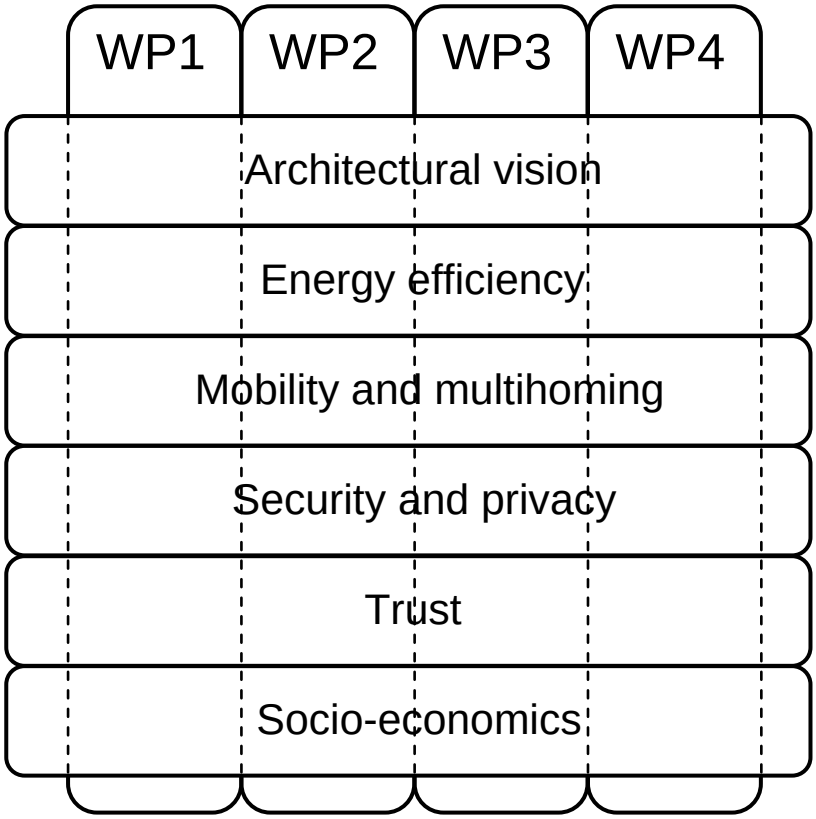

Figure 1: Overview of workpackages and cross-workpackage issues

The Cross-workpackage topics

Cross-workpackage topics

Architectural vision: A core component of the work in the programme relates to defining new architectures to support our vision/idea of the future Internet. This issue coordinates the work done in the different workpackages and ensures that a coherent vision for the future Internet will come out as a result.

Energy awareness: Energy-constrained systems, such as mobile terminals, draw their charge from a finite battery. Thus the battery capacity is a fundamental limitation and energy minimization is a valid design goal. This motivates both static and dynamic optimization of the whole software execution environment at all levels of system design, including device, architectural, compiler, OS, networking, and application layers.

Mobility and multihoming: The Internet was not designed with mobility or fine-grained multi-access in mind. Consequently, there are issues related to mobility support at all layers and aspects of the current Internet design. In all mobility, the easier part is mobility before communication, i.e., updating reachability information of an entity in the network. The harder part is mobility during communication, when data is flowing between parties. Further challenges include

actual deployment of various extended mobility schemes, authentication of location updates, and privacy of one's location and movement. Multihoming is today is key part of network and capacity engineering, and as such has provided to the growth in routing tables and the problems with currently see in the Internet routing infrastructure.

Security and privacy: Security and privacy are fundamental requirements for today's distributed applications and services. This cross work package issue follows security requirements and solutions developed in the work packages, and facilitates cross work package cooperation and collaboration regarding this topic. Security issues need to be considered on multiple layers, and also from cross-layer viewpoint to ensure good integration and security support for applications. Performance and energy usage issues need to be considered also from the viewpoint of the security solutions.

Trust: Trust is a human thing. For our purposes, trust is a way of reducing the mental or informational transaction costs involved in economic activities. The human aspect of trusting is evolutionally (and socially) built aptitude for, by default, believing, to a varying degree, that other people are primarily good and do not aim to (seriously) harm us. More specifically, people have an innate ability to interpret a range of signals that will influence their behavioural, trust-related strategies. In real-space, cues, such as facial expressions, voice, and body language betray some of our internal code, lowering trust related transaction costs. Nevertheless, solving the problem of trust has been, and indeed continues to be, one of the key issues in the rise of global commerce ever since the antiquity.

Socio-economics: Many of the present problems and future challenges of the Internet appear to require not only technical solutions, but also taking into account the relative positions, incentives, and objectives of the various stakeholders. In particular, we need solutions where the stakeholders will find it attractive to co-operate in a way that facilitates the smooth and transparent operation of the network and the emergence of innovations. To achieve this, the socio-economic issues and properties of internetworking must be considered across all relevant parts of the work.