Towards Future Internet Architecture

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1. Towards a Future Internet Architecture

2. Remarks on Future Internet Design Goals
Some Definitions for Distributed Systems

- **Functional requirements** are defining specific behaviour functions of a system. In a system
  **Non-functional requirements** are specification criteria that can be used to judge the
  operation of a system, rather than specific behaviours. **A system limit** is a system condition
  that it identifies the sudden changes in behaviour functionality of a system arising from
  insignificant changes in circumstances of a system.

- In general **Functional Requirements** define *what a system is supposed to do*, **non-
  functional requirements** define *how a system is performing its functions*, whereas the
  **system limits** define the *constraints and freedoms in controlling the system*. Limits can
  be determined by analysing how the behaviour of the system depends on the parameters
  that drive the system. Some limits would lead to unexpected and significant behaviour
  changes of the system, for example the unpredictable boundaries or changes in the scale of
  magnitude. Some other limits are determined by non-common behaviour interactions
  between the components of a system.

- **System Design** - a plan for implementing functional requirements.
- **System Architecture** - a plan for implementing non-functional requirements within the
  system limits.

- **A specification of a distributed system** like Internet can be realized by describing and
  measuring **combinations of Functional Requirements, Non-functional Requirements and System Limits**.
- **A system architecture** is a **conceptual model that defines the structure, behavior, and a
  number views of a system within the system limits**.
Key Changes in Current Internet - History

- Changes were possible when the Internet was still an academic research network (i.e. until 1993 when the WWW turned it to a commercial)

- Inter-network that underpins the “information society”

- Key changes in that period were the following: 1982 DNS, 1983 TCP/IP instead of NCP, 1987 TCP congestion control, 1991 BGP policy routing, 1991 SNMP

- No significant changes since then apart from MPLS which has been deployed in addition to plain IP

- Research efforts towards the Future Internet: evolutionary & clean-slate approaches and changes, autonomic management
Towards a new Network Model

Current Internet

- A Concatenation of Networks interconnected by IP functionality (i.e. L4-7 Interconnected and uncoordinated networks).
- Infrastructure where intelligence is located at the edges.
- Just general design guidelines (i.e. not binding and not enforced; no formal prescriptive principles) and some protocols.
- Simple network layer / abstraction for data plane: IP’s best effort & TCP’s reliable byte-stream; Terrible Interfaces: IP embedded in TCP; violates principle of modularity
- No Control abstraction: no sophisticated management; no control building blocks; increased complexity with new control requirements
- Services are realised at the end-hosts.
Towards a new Network Model

How to control Networks: current approaches

- Define new protocols from scratch (e.g. routing)
- Design new (ad hoc) mechanisms (e.g. traffic engineering)
- Delegate it to the manual operator configuration (e.g. access control, middleboxes) \(\rightarrow\) significant increases in OPEX

Current Tussle: Mastering Complexity Vs. Extract Simplicity

\(\leftrightarrow\) Creating more (new) mechanisms Vs. defining right abstraction

Significant trends of the last 5-7 years

- Internet is becoming both a connectivity and service execution/computation environment \(\rightarrow\) service aware connectivity infrastructure
- Computation, storage and connectivity have been virtualised separately and in an integrated way \(\rightarrow\) resulting in a flexible and cost effective infrastructure with elastic usage and sharing resources
- A segmentation of IP processing/computation
Towards a new Network Model

New Terms

- **Software Defined Networking (SDN)** is a term coined by Kate Greene and refers to a network architecture in which the network control plane is decoupled from the physical topology. Such a decoupling was also promoted by the active/programmable networks community. The rational for this approach is twofold. First, the decoupling allows for the control plane to be implemented using a different distribution model than the dataplane. Second, it allows the control plane development and runtime environment to be on a different platform than the traditionally low-powered management CPUs found on hardware switches. SDN requires some method for the control plane to communicate with the switch datapath. One such mechanism is OpenFlow which is a standard interface for controlling computer networking switches. OpenFlow is often confused to be equivalent to SDN. However, there is no requirement for the use of OpenFlow within an SDN.

- **Future Networks / Future Software Driven Networks (SdNET)**

Unlike the original Internet infrastructure set of standards, which merely focus on technical connectivity, routing, and naming, the scope of the SdNET recommendations, standards, and guidelines should encompass all levels of interfaces and execution environments for Services, Manageability and Technical Resources (networking, computation, storage, control)

- Infrastructure where the intelligence is embedded at all levels, enabled and programmable.
- Substitute KISS principle with KII principle: “Keep it intelligent” (i.e. today fundamental is tomorrow’s secondary)
Future Software Driven Networks - Model

Requests \(\downarrow\) Application Programming Interfaces

Service-aware & Management-aware Control functions

Virtualization & Programmability functions

System Programming Interfaces

Networking, processing and storage - physical resources (Physical Infrastructure-Resources)

Operator Control

Applications/Services

Control Plane

Data & Resource Plane
New Network Model – Future Software Driven Networks
New Network Model – Future Software Driven Networks

Execution environments

Network Control Plane: Network Operating System Facilities

Protocols

Server Hardware

Management Applications

Control Applications

Network Applications

Operating System

Packet Forwarding Hardware

Protocols
New Network Model – Future Software Driven Networks

In-bound cognitive management

Extensible Network Distributed Operating Systems Facilities
- Possible open source
- Provide a logical global view of the network
- Support for distribution
- Support for state collection / dissemination
- Support for execution environments
- Support for Orchestration & Coordination
- Knowledge & Information
- Governance & Configuration Interface for Operator

Open APIs

Network Control Plane: Network Operating System Facilities

Open Interfaces to Forwarding hardware

Protocols

In-bound cognitive management

Network Apps

Execution environments

Manager Apps

Control Apps

Network Apps

Packet Forwarding Hardware

Operating System

Packet Forwarding Hardware

Operating System

Packet Forwarding Hardware

Operating System

Server Hardware

Protocols

Protocols

Protocols

Protocols
Keys Elements of Future Software-Driven Networking

• Management is the key functionality of FI/ Future Software Driven Networking
• Separation of Control Plane & Data Plane with Open API Between the Two
• Logically Centralized Control-Plane with Open API to Applications
• Network & Computation Virtualization / Resource utilisation and Elasticity
• Programmability of the Infrastructure
• Life-cycle Manageability of the Infrastructure
• Support Execution Environments for Infrastructure Applications: In-bound Cognitive Management, In-Bound Control, Network Applications
• Creates Open Interfaces between Hardware, OS and Applications Similar to Computer Industry

• Increases Competition, Enables Innovation
• Controlling OPEX Costs & Enabling Grows in Value of the Networks
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Objective: Recommendations for future networks (i.e. 2015+)


Results:

- Y.3001 Recommendation “Future Networks - Objectives and Design Goals”
- Y.3011 Recommendation “New Framework of network virtualisation for Future Networks”
- Y.3021 Recommendation “New Framework of energy saving for Future Networks”

With contributions, concepts & references from FIA MANA & FP7 projects: AutoI, RESERVOIR, 4WARD, UniverSELF

Chairman: Takashi Egawa (NEC, Japan) - 2010
Morita Naotaka (NTT, Japan) - 2009

Vice-Chairman: Hyoung Jun Kim (ETRI, Korea)
Vice-Chairman: Alex Galis (University College London, UK)
Future Networks/Internet: Objectives & Design Goals

ITU-T Recommendation Y.3001 “Future Networks - Objectives and Design Goals”

- Environment awareness
  - FNs should be environmental friendly.
- Service awareness
  - FNs should provide services that are customized with the appropriate functions to meet the needs of applications and users.
- Data awareness
  - FNs should have architecture that is optimized to handling enormous amount of data in a distributed environment.
- Social-economic awareness
  - FNs should have social-economic incentives to reduce barriers to entry for the various participants of telecommunication sector.
ITU-T Recommendation Y.3001
“Future Networks - Objectives and Design Goals”

1. Service Diversity
2. Functional Flexibility
3. Virtualization /resources
4. Data Access
5. Energy Consumption
6. Service Universalization
7. Economic Incentives
8. Network Management
9. Mobility
10. Optimization
11. Identification
12. Reliability & Security

Objectives

Design Goals
ITU-T Recommendation Y.3001
“Future Networks - Objectives and Design Goals”

- Service awareness
  - Service Diversity
  - Functional Flexibility
  - Virtualization of Resources
  - Network Management
  - Mobility
  - Reliability and Security

- Data awareness
  - Data Access
  - Identification

- Environmental awareness
  - Energy Consumption
  - Optimization

- Social and economic awareness
  - Service Universalization
  - Economic Incentives
Future Networks - 12 Design Goals

- **(Service Diversity)** FNs should accommodate a wide variety of traffic and support diversified services.

- **(Functional Flexibility)** FNs should have flexibility to support and sustain new services derived from future user demands.

- **(Virtualization of resources)** FNs should support virtualization so that a single resource can be used concurrently by multiple virtual resources.

- **(Data Access)** FNs should support isolation and abstraction FNs should have mechanisms for retrieving data in a timely manner regardless of its location.

- **(Energy Consumption)** FNs should have device, system, and network level technologies to improve power efficiency and to satisfy customer’s requests with minimum traffic.

- **(Service Universalization)** FNs should facilitate and accelerate provision of convergent facilities in differing areas such as towns or the countryside, developed or developing countries.
• (Economic Incentives) FNs should be designed to provide sustainable competition environment to various participants in ecosystem of ICT by providing proper economic incentives.

• (Network Management) FNs should be able to operate, maintain and provision efficiently the increasing number of services and entities.

• (Mobility) FNs should be designed and implemented to provide mobility that facilitates high levels of reliability, availability and quality of service in an environment where a huge number of nodes can dynamically move across the heterogeneous networks.

• (Optimization) FNs should provide sufficient performance by optimizing capacity of network equipments based on service requirement and user demand.

• (Identification) FNs should provide a new identification structure that can effectively support mobility and data access in a scalable manner.

• (Reliability and Security) FNs should support extremely high-reliability services.
Technologies - achieving the design goals

- **Virtualization of Resources (Network Virtualization)**
  - Enables creation of logically isolated network partitions over shared physical network infrastructures so that multiple heterogeneous virtual networks can simultaneously coexist over the shared infrastructures; it allows the aggregation of multiple resources and makes the aggregated resources appear as a single resource.

- **Data/Content-oriented Networking (Data Access)**

- **Energy-saving of Networks (Energy Consumption)**
  - Forward traffic with less power
  - Control device/system operation for traffic dynamics
  - Satisfy customer requests with minimum traffic

- **In-system Network Management (Network Management)**

- **Distributed Mobile Networking (Mobility)**

- **Network Optimization (Optimization)**
  - Device / System / Network level optimization (Path optimization, Network topology optimization, Accommodation point optimization)
Acknowledgement and Some References


UniverSELF FP7– www.universef-project.eu
(For the In-bound Management / Universal Management Framework concepts)
