Enabling Future Internet Architecture Research and Experimentation by Using Software Defined Networking

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Agenda

• Introduction
• SDN
• OpenFlow versions
• Future Internet Architecture Research and Experimentation
  – Experimental Facilities
  – Research Initiatives
• Concluding Remarks
Introduction

• Internet was designed in totally different context, far from of what he have today
• New applications define a new set of requirements that are not satisfied by the current Internet
• Researchers are engaged in designing a new Internet using a clean slate approach
• SDN, current materialized in OpenFlow enable researchers to innovate in computer networks
• SDN represents an extraordinary opportunity to rethink computer networks
SDN

- Deployment and experimentation of new network architectures is really difficult even at a laboratory inside a campus
- Researchers are *locked* in their networks
- SDN decouples the software that controls the network elements from the hardware
- SDN enables the deployment and experimentation of new network architectures
OpenFlow

- SDN, currently, is materialized in OpenFlow
- OpenFlow separates the data plane from the control plane of switches
## OpenFlow Versions

<table>
<thead>
<tr>
<th>Version</th>
<th>Release Date</th>
<th>Flow Tables</th>
<th>Number of Match Fields</th>
<th>Extensible Match Support</th>
<th>Availability</th>
<th>Mandatory Actions</th>
<th>Optional Actions</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>12/31/2009</td>
<td>1</td>
<td>12</td>
<td>No</td>
<td>Software and Hardware</td>
<td>Forward, Drop</td>
<td>Forward(^1), Enqueue, Modify-Field</td>
<td>Ethernet, IP, TCP</td>
</tr>
<tr>
<td>1.1</td>
<td>02/28/2011</td>
<td>Pipeline</td>
<td>15</td>
<td>No</td>
<td>Software</td>
<td>Output, Drop, Group</td>
<td>Output(^1), Set-Queue, Push-Tag/Pop-Tag, Set-Field</td>
<td>1.0 protocols + MPLS</td>
</tr>
<tr>
<td>1.2</td>
<td>12/05/2011</td>
<td>Pipeline</td>
<td>36</td>
<td>Yes</td>
<td>Software(^2)</td>
<td>Output, Drop, Group</td>
<td>Set-Queue, Push-Tag/Pop-Tag, Set-Field, Change-TTL</td>
<td>1.1 protocols + IPv6</td>
</tr>
<tr>
<td>1.3</td>
<td>04/16/2012</td>
<td>Pipeline</td>
<td>40</td>
<td>Yes</td>
<td>Not yet</td>
<td>Output, Drop, Group</td>
<td>Set-Queue, Push-Tag/Pop-Tag, Set-Field, Change-TTL</td>
<td>1.2 protocols + IPv6 Extension Headers</td>
</tr>
</tbody>
</table>

1 - The forward (output) to some types of defined ports is optional.
2 - Recent released versions.
Future Internet Architecture Research and Experimentation

Experimental Facilities

- Current Internet development was based on experimental research using the ARPANET
- OpenFlow can enable an experimentally oriented research based on large test beds
- Opportunity to use appropriate scales that are required to a new Internet architecture
- OpenFlow based Facilities
  - USA: GENI
  - EUROPE: OFELIA
  - BRAZIL: FIBRE and OFELIA
    - Intercontinental OpenFlow based infrastructure
Future Internet Architecture Research and Experimentation

Research Initiatives

• Some research groups are focusing the use of SDN and OpenFlow

• Research is related with new network architectures that addresses future Internet requirements.

• Initiatives described here have in common:
  – Vision of a new protocol stack and the use of new naming and addressing schemes
  – Use of OpenFlow for experimentation
Research Initiatives

• USA
  – NSF FIA (Future Internet Architecture) Program
  – Aims to design and evaluate new Internet architectures.
  – Five granted projects
  – Two of them, are considering at this moment the use of OpenFlow (MobilityFirst and XIA - eXpressive Internet Architecture)

• Europe
  – Several projects under FP7 program regarding Future Networks
  – COntent NETwork (CONET)
    • Under the context of OFELIA

• Brasil
  – Entity Title Architecture (ETArch)
  – Lead by our research group and other Brazilian Institutions
  – Network architecture that naturally fits on the SDN approach
Research Initiatives
MobilityFirst

- [http://mobilityfirst.winlab.rutgers.edu/](http://mobilityfirst.winlab.rutgers.edu/)
- Mobility is a fundamental design goal regarding future Internet
- Key aspects
  - New naming scheme based on a Globally Unique Identifier (GUID) mapped to a flat Network Address (NA)
  - Generalized Storage-Aware Routing (GSTAR) uses an adaptable mechanism that handles varying link quality and disconnection
  - Global Name Resolution Service (GNRS), distributed over the routers, that is responsible for mapping the GUID to a network address
- Experimentation
  - Project has three phases for prototyping and evaluation
  - First phase assumed prototyping using a software router based on Click
  - Moving to an OpenFlow enabled prototype
Research Initiatives

XIA - eXpressive Internet Architecture

- [http://www.cs.cmu.edu/~xia/](http://www.cs.cmu.edu/~xia/)
- Clean slate, trustworthy and evolvable network
- Key aspects
  - First class citizen at the architecture is called Principal (content, a service, a host, a user)
  - Naming scheme based on the a Principal identification that is generated by hashing a public key
  - Addressing scheme based on a Directed Acyclic Graph (DAG) that contain the Principal’s identifier at each hop
- Experimentation
  - The first prototype of XIA architecture uses a XIA router based on Click
  - They will implement XIA forwarding engine using OpenFlow
  - Expectation that the OpenFlow based implementation will be faster than the current prototype
  - This implementation will allow to scale current experiments, performing more realistic evaluation of the architecture over GENI
Research Initiatives
CONET (COntent NETwork)

- http://netgroup.uniroma2.it/twiki/bin/view/Netgroup/CoNet
- Based on the content-centric paradigm where content is the first class citizen
- Key aspects
  - Network architecture has a layer capable of providing the users access to Named Resources (Content or Services)
  - Network consists of several CONET nodes interconnected by CONET Sub Systems (CSS)
  - Type of Nodes: End Nodes (EN), Serving Nodes (SN), Border Nodes (BN), Internal Nodes (IN) and Name Routing System Nodes (NRS)
  - Nodes exchange CONET Information Units (CIU) that can express an interest on some named-data or chunks of this named-data
  - Two different approaches regarding the packet format: one is based on a clean slate packet and other that uses IPv4 or IPv6 options to carry CONET related information
- Experimentation
  - CSS deployed under OFELIA (OpenFlow 1.0 based network) by mapping the content name into TCP source and destination ports
  - Flow Tables are modified in a reactive mode to get general processing rules and in proactive mode in the event of new contents cached
Research Initiatives
CONET (COntent NETwork)

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Research Initiatives
Entity Tile Architecture (ETArch)

- [http://www.mehar.facom.ufu.br/](http://www.mehar.facom.ufu.br/)
- Entity (content; sensor; a smart phone; an application) is the first class citizen.
- It has a Title and communication requirements and capacities which can be semantically understood from top to bottom layers
- Key aspects
  - Based on a new naming and addressing schema, called workspace, where Multicast and Mobility are seamlessly provided
  - Architecture components: Domain Title Service (DTS), DTS Agent (DTSA), OpenFlow based substrate
  - Title is a topology independent designation to ensure an unambiguous identification of an entity
  - DTS deals with all the control aspects of the network
- Experimentation
  - OpenFlow was our first choice for experimentation
  - Flow table handles the information to produce the workspace materialization (Ethernet source and destination addresses plus the VLAN are mapped to the workspace Title)
  - First prototype of ETArch was deployed and experimented at OFELIA
  - Research agenda now considers integration with IEEE 802.21 implementation to support the vertical handover optimization in the presence of multiple access networks
Research Initiatives

Entity Tile Architecture (ETArch)

- Basic infrastructure
- DTS composed of DTSAs
- DTSAs contains an OpenFlow Controller

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• A service, which title is “workspace1” is made publicly available.
• “Application1” want this receive this video stream
“Application1” query DTSA\textsubscript{1} for the “Workspace1”.

DTSA\textsubscript{1} contact other DTSAs peers and discover “Workspace1”

Workspace is modified to handle new requirements
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Application1

Application2

Workspace1

"Application2" query DTSA₁ for the "Workspace1".

Workspace is modified to handle new requirements, meeting multicast aggregation.
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- "Application1" moves through the DTS
- Workspace is modified to handle new requirements, meeting mobility
Concluding Remarks

- Considering a new set of requirements Internet architecture must be reviewed
- Deployment and experimentation of new network architectures is difficult even at a laboratory inside a campus
- At different continents, wide OpenFlow enabled infrastructures are available to research groups enabling an experimental evolution of future Internet
- By using OpenFlow version 1.0, different research groups, at different stages, are experiment new network architectures
- Semantic of each architecture must be mapped to the 1.0 match fields
- OXM, recently available at software, is suitable for a new network architectures
- OpenFlow, the deployed vision of SDN, represents today the most viable alternative to experiment, at scale, new network architectures