

Flexible Architecture for the Future Internet

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Outline

- Motivation: Why do we question the Internet architecture?
- Major Future Internet research initiatives
- A flexible and innovation-friendly architecture using network virtualization

Is there something wrong with the Internet?

Some of today's unsolved challenges

- Security
 - DoS, Spam, viruses, authentication, ...
 - Internet was designed with cooperating systems in mind
 - Has only local mechanisms (firewalls etc.), but no global security concept
- Mobility
 - Internet uses same ID for naming and locating hosts
 - Combined with hierarchical addressing, mobility is hard
 - Highly dynamic network paths
- Scalability
 - Routing system is reaching limits
 - Are we prepared for massive numbers of communicating “things”?
 - Sensors, tags, embedded devices, ...
 - IPv6 migration still very difficult
 - Operational complexity
 - ...
- Manageability
 - Enormous operational complexity (especially cross-domain)
 - Again, only distributed, local solutions, but no overarching concept and “management plane”
- QoS
- Availability
- ...

How can we change things?

- **“Patching the Internet” – a dead end?**

E.g.:

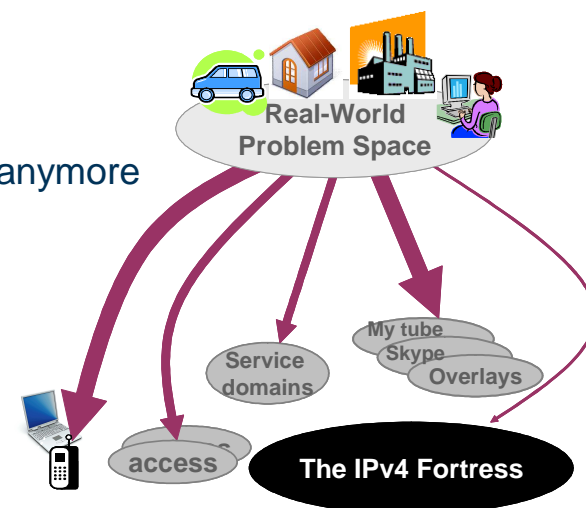
- Scalability:
 - Break global addressing (NATs) and change packet format (IPv6) to combat address shortage
 - Keep adding memory to routers for growing routing tables
- Security
 - Break E2E transparency (firewalls, NATs)
 - Let applications and end hosts deal with security
- Mobility
 - Tunneling
 - Breaking routing hierarchy
 - Changing IDs
- ...

- ⇒ **Fundamental Internet design principles are violated**
 - ⇒ A sign that they are not meeting today’s challenges anymore
- ⇒ **Operational complexity is growing with each “patch”**

- **The Internet itself is increasingly resisting innovation (“ossification of the Internet”)**

- “Deployment stalemate”
- Incentives/revenue sharing for ISPs vs. net neutrality
- Slow standardization processes

- ⇒ **Innovation is today almost exclusively happening in applications and at the edges**
- ⇒ **How can we bring innovation back into the network?**



A *Clean Slate* Approach

- **Clean slate ...**
 - ... **thinking**
 - How would we design the Future Internet If we could start from scratch?
 - “Out of the box” thinking
 - No legacy constraints
 - ... **evaluation**
 - Prototyping and experimentation are crucial
 - What kind of experimental facilities are needed to test revolutionary approaches at scale?
 - ... **deployment**
 - “Clean slate” does not mean “throwing away the Internet”
 - Some ideas may be retrofitted into the Internet
 - Co-existence of architectures?
 - Migration towards the Future Internet?

Major Future Internet initiatives



Europe

- FP 6
- FP 7
 - Network of the Future
 - 4WARD
- FIRE

Japan

- New Generation Networks
 - AKARI

Korea

China

- planning

USA

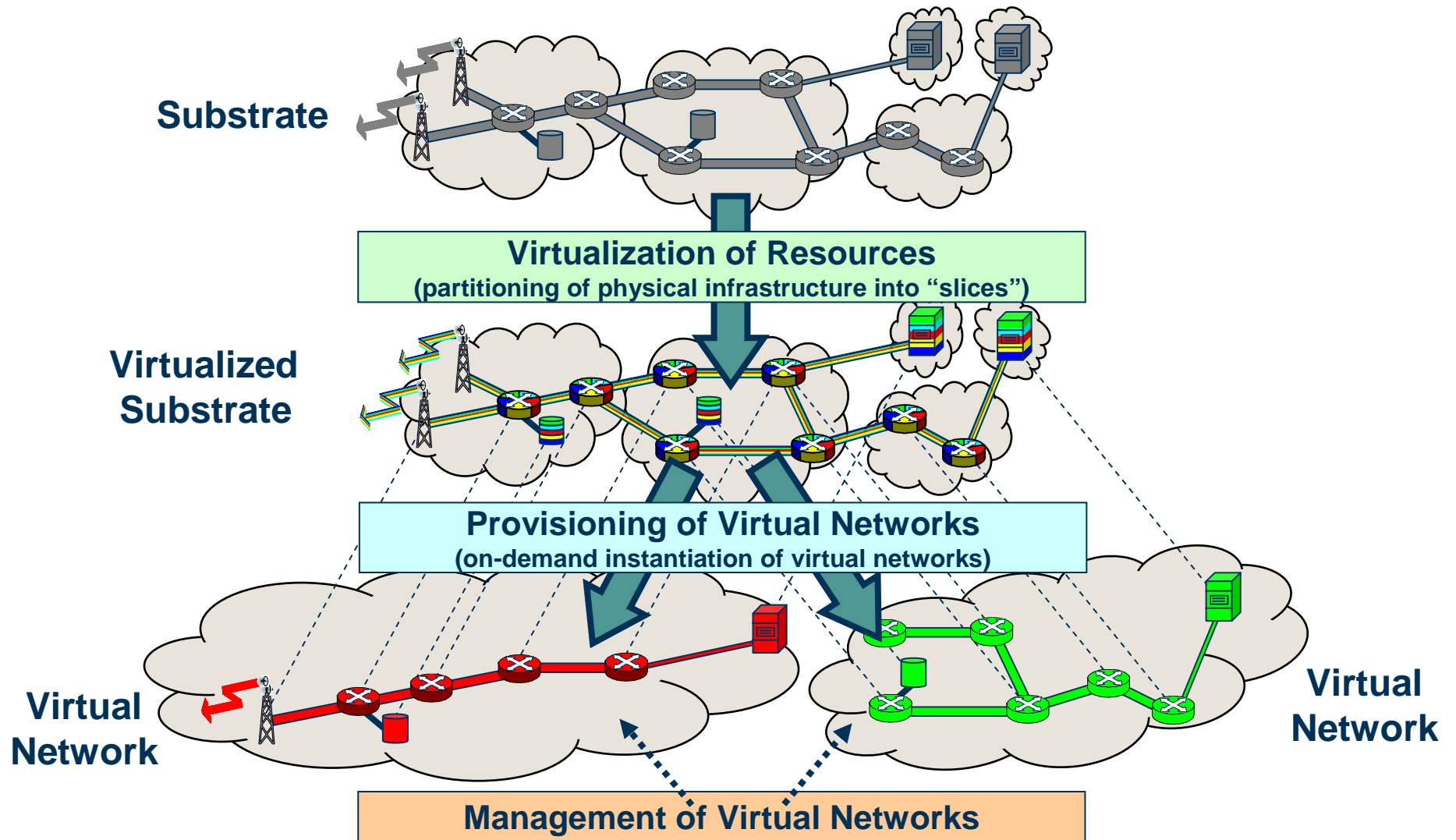
- FIND
 - 28 small independent projects
- GENI in preparation

Lessons learned

- The Internet architecture is not a “one size fits all” solution
- Many of today’s problems exist because the Internet is used for things it was not designed to do
 - Unforeseen developments require new solutions
 - New applications, communication patterns, technologies
- **It is unlikely that we can come up with a single “universal network”**
- **It is unlikely that any network we design now will meet the new requirements of the future**
- **Use virtualization as the basis for an innovation-friendly, open architecture!**
 - Co-existence (separate, but interworking where desired)
 - Deployment of new networks in the future
- Wanted: A systematic approach to network virtualization



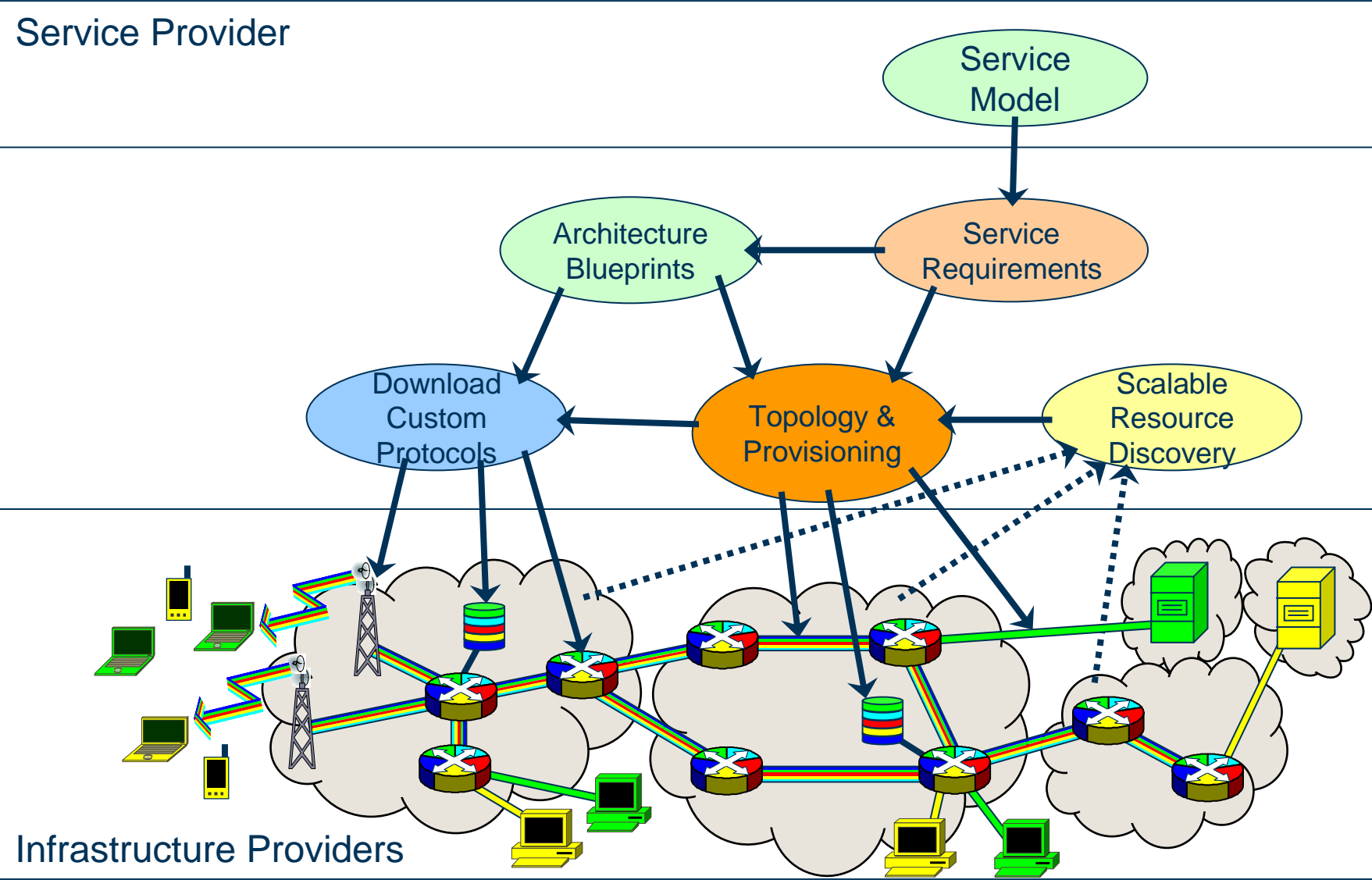
Network Virtualization in 4WARD



What can virtualization do for us?

- Deployment and coexistence of innovative new approaches as well as legacy systems in a commercial setting
 - Temporary (migration) or permanent
- Empower service providers to deploy novel E2E services without requiring Internet-wide consensus
 - Overcome “deployment stalemate”
- Flexible resource allocation
 - Set aside resources for high-priority traffic
 - E.g. “Blue Light” applications: Shift physical resources to public safety networks in case of an emergency
- Open up the market for new business roles and competition
 - Trading of infrastructure resources
 - Separation of infrastructure and service providers
- Cost-efficiency by sharing infrastructure resources

Instantiating Virtual Networks On Demand



4WARD Virtualization Framework

1. Scalable provisioning of virtual networks

- Discover, provision, configure, and aggregate virtual resources on a large scale
 - Resource description
 - Type, capabilities, capacity, connectivity, cost, ...
 - Resource trading / bidding
 - Build topology (including mobile and volatile resources)
- On-demand instantiation of new virtual networks

2. Virtualization management

- Deployment and control of virtual network resources
- Dynamic reallocation of resources
- Manage volatile/mobile infrastructure resources
- Revenue steering, billing, charging

3. Folding points

- Controlled transition between virtual networks
- Connectivity and interworking
- Address and data format conversion
- Protocol translation

Virtualization of Resources in 4WARD

- Allow customization of programmable resources for maximum flexibility
 - Protocol software download/installation
- Standardized Virtualization Management interfaces
 - Discovery
 - Instantiation of new virtual resources
 - Provisioning
 - Control
- Protection of shared infrastructure assets via sandboxes
- Secure separation of virtual networks

- Fixed resources
 - Routers, switches, links, network storage, ...

- Wireless resources (spectrum, wireless infrastructure, mobile nodes)
 - Virtualization of spectrum via
 - FDMA, TDMA, CDMA, spatial separation
 - Virtual basestations
 - Virtualization in the MAC layer
 - Allow co-existing, specialized RLC protocols
 - Mobile nodes as infrastructure resource
 - How to deal with mobile/volatile resources?

Conclusions

- The original Internet design is increasingly unable to meet the new requirements posed by new applications, changing communication patterns, and new technologies
- Fixing the problems within the original design space is becoming increasingly difficult
- *Clean Slate* thinking and design could help us to overcome the impasse
- Virtualization as the basis for an innovation-friendly and extremely flexible network architecture
 - Co-existence of networks to meet diverse requirements
 - Deployment of radically new approaches as requirements change in the future
- Needed:
 - Scalable framework for the systematic provisioning, management, and interworking of virtual networks
 - Methods to make a broad variety of resources efficiently and securely shareable through virtualization

Thank you!