Software Defined Technologies - What's next?

Report on experts' consultation
December 2016

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"Technology unlocks use cases, use cases drive scale, technology adapts to scale, new use cases emerge, and a cycle of growth continues." Y. Kumar (CORSA Technology)

Challenges

Internet ossification: The core of the Internet (backbones composed of routers and switches) cannot easily transform to support new demands, let alone innovation. Virtualization support in network devices can address this limitation, as software-based capabilities to address specialized requirements can be deployed on virtual devices without disrupting the established Internet.

Open ecosystem: The challenge here is to create an ecosystem of silicon, hardware, operating system/control-management plane software and applications for the next generation Internet, building upon the momentum of the data center industry. An open ecosystem is also good ground to revisit existing technologies and protocols, and enhance or create new as needed. OTTs like FB are challenging vendor lock-in through programs like TIP. An open ecosystem has the potential to disrupt the networking vendor ecosystem, and Europe should come up with its own initiative on this regard.

Data-driven disruption: Data and its computation are heavily affecting the Internet evolution. Network topologies have been transforming with data centers in the middle. Machine to machine communication comes next and data flows will change again. New technologies and protocols are needed.

Incumbency: Vendor/provider incumbency in the form of closed/proprietary software platforms is a barrier towards a truly software-oriented Internet and brings back the limitations of proprietary solutions of the current Internet market. Privacy and ownership are still challenged by large corporations that influence the new generation of networking. Openness in all layers of the network software stack is essential for next-generation Internet innovation and competitiveness. Enabling access to the services running on top of the Internet in smaller scales is a major challenge.

Social impact: The upcoming Internet epoch, driven by technologies in the areas of 5G, cloud computing, machine learning and network security, is expected to affect human lives in an unprecedented way, as data on our movements, interests and thoughts will be used to deliver our services and machines will be more involved in looking after our needs.

Convergence: Mobile and fixed networks are expected to converge fully to cloud platforms and functions. There are several technology, regulation and business challenges ahead of this convergence.

Diversity: IoT, industrial Internet, xK video, connectivity to cloud-based AI and other emerging applications introduce a variety of functional and performance requirements such as heterogeneous access, in-network adaptation, connectionless communication, on-board caching etc.

Bridging the divide: In a rapidly changing Internet, with softwarization and virtualization changing the terms of play, there is a number of incompatibilities between agile service providers, vendors and the traditional telcos. NGI may serve as a research programme that supports cross layer developments.

SDx ecosystem: The ecosystem of developers is critical in leveraging upon the potential of SDN/NFV. Following the shaping of the Internet by selected engineers in standards' organizations, now softwarization enables a much wider base of engineers/companies to design and implement the protocols and networks of tomorrow. NGI is challenged with enabling leadership in order to mobilize effectively the wide base of European researchers in that direction.

Devices' and software elements' marketplace: Innovation is possible when small developers of Internet solutions can compete with large network vendors by selling COTS hardware and specialized software elements that deliver specialized features for networking. Such a marketplace is a prerequisite for NGI.

Key research areas

Software-based control plane: NGI initiatives can have a tremendous impact in the development of optimized open-source control plane solutions. A key element of SDN and virtualization is the software router, using general purpose hardware for packet routing and forwarding. Out of the existing open-source routing control plane solutions (Quagga, BIRD, Vyos etc.) implementing basic routing protocols, different protocol implementations are incompatible or not existent at all (e.g. RSVP), while code documentation and performance is not adequate. An efficient open routing stack is missing and could form the basis of the next generation Internet. Subsequently, efficient open source controllers developed with industry engagement would enable wide deployment of software-based offerings in production. At the same time, abstraction approaches for controlling overlay networks (such as OVN) and core routing (such as segment routing) are put forward, bypassing traditional networking. Such capabilities are expected to be in the core of NGI and have the potential to disrupt the router market, with Europe's leadership.

Programmable data plane: Abstracting the ASIC functionality through an API unlocks innovation. With the advent of programmable hardware and relevant programming languages (e.g. P4), programmability is not confined to the control plane anymore and the data plane now has the ability to flexibly maintain state at line rate. This enables future networks with better performance and also better monitoring capabilities. Furthermore, software platforms for high-speed data planes (such as netmap, DPDK, FD.io and psio) present an opportunity for efficient forwarding of short packets, addressing throughput degradation (e.g. of existing PCIe slots). Programmability then allows for the implementation of only selected (existing or novel) protocols. Optimization of the data plane, in particular for data center applications, can be a field of European innovation in the NGI context (however innovation often stumbles upon the lack of qualified kernel developers).

Service plane evolution: The invention of new concepts like Network Service Headers (NSH), Locator ID Separation Protocol (LISP) and GENEVE encapsulation for the edge are essential. They will either happen using an IETF standard process, or new competing solutions will come to market leveraging the flexibility of programmability at the data and control plane.

Disrupting the architecture: In today's Internet, network functions are organized in stacks of layers, each of which performs a different function (e.g. physical access, addressing, routing) implemented by different protocols, while enhancements (e.g. tunnelling) have created a more complex layering environment. NGI can foster disruptive approaches to the stacked architecture further than existing ones, such as the Recursive InterNetwork Architecture using inter-process communication principles to deliver networking services. Facilitating approaches that transform the Internet architecture as we know it today is imperative in order to overcome well-known limitations.

Interface standardization: Just like in the case of IETF-driven efforts for the current Internet, software-based networks and virtualization/layering will only be adopted at a large scale when significant advances in interfaces' standardization occur. Related efforts (such as the OpenFlow interface, ETSI MANO APIs, the ONF NBI) are noted, however, there is a lot more to be achieved to enable wide-scale deployment of software-based capabilities

Softwarizing the (unlicensed) wireless access: A large part of Internet traffic is carried over unlicensed spectrum, mostly 2.4GHz and 5GHz band, but in the near future also the 868MHz (for IoT) and the 60GHz band (for very high throughput). Technologies operating in these bands span from IEEE 802.11, 802.15 but also LTE. Building open reference implementations for these wireless access networks is a catalyzer for innovation in a variety of applications, especially the IoT. For example it would be useful to develop open APIs to control linux based wireless devices (e.g standardized NETCONF agents for linuxwireless). If these APIs are supported by the community (linux), then we could unlock a lot of innovation on top of "white wireless boxes", which would compete with closed vendor wireless solutions typically found in enterprise/campus deployments today

Agility: With the advent of SDx and NFV, network functions can be offered via microservices, release cycles can be shorter and new features can be deployed in larger volumes and via continuous live testing. Also migrating from the legacy network to software-defined, virtualized networks is made possible by partially deploying advanced features or new devices in existing networks, with relevant efforts already observed globally. Applying agile software development techniques to the networking control plane is going to be essential for the next generation Internet. A commercially deployable model for software-based features will unleash a tremendous volume of added-value offerings to the Internet user base.

Autonomic management: Traditional network management cannot cope with the multiplicity of devices (physical or virtual) and the complexity and size of the next generation Internet. Therefore autonomicity and self-management will be essential for networks and devices, also based upon high-level management intents applied in different scopes and contexts. A challenge is to prove whether recent advances in ML, e.g. deep reinforcement learning, are amenable to enable network automation

Security: Both securing the software-driven network infrastructures and leveraging programmability features to introduce flexible security capabilities in future networks are in scope. For example, one can now make the network devices defend themselves upon attacks. Ubiquitous encryption is also impacting data transport, as a conflict between service providers and telcos. Trustworthiness, Provenance, Privacy should also be considered (see also RFC 7258)

Performance and utilization: Network programmability allows for flexible use of network resources and as such provides the means for improved performance and utilization. However, current technologies such as OpenFlow, which handles traffic on a flow basis, leave room for improvement (e.g. packet-based optimizations). More powerful forwarding (hop-by-hop and multipath support) as well as transport (e.g. caching for local retransmissions) are also important for the next generation Internet to serve the diverse access and application base.

Scalability and resiliency: In order to cope with mass-scale deployments, software-based networking needs to address scaling up aspects. Also resiliency of software and hardware based elements to ensure the minimum failover times of today's Internet or even better ones. Along these lines, de-centralizing functionality (e.g. moving parts of specification, computation and provisioning of the forwarding state from a central controller to distributed control plane elements or even to network devices directly) is a key element for research on the next generation Internet. Mobile Edge Computing, or Fog computing, are other emerging trends in this domain which should be addressed by NGI.

Service delivery models: Software networking and programmability transcend the borders of different administrative network domains and disrupt traditional service delivery models. Much greater dispersion is now observed, more flexible business arrangements are possible, entities such as virtual carriers can emerge. Flexible provisioning, resource brokerage between providers and dynamicity in resource allocation/de-allocation provide the basis for new delivery models in next generation networks.

Beyond tech: The impact of Internet evolution, novel applications, disruptive service delivery models and ubiquitous access as well as the works of groups such as IRTF's GAIA (Global Access to the Internet for All Research Group) provide the starting point for addressing NGI aspects beyond technology.

Expected impacts

- Innovative services to the society, like life replay, global education, immersive experiences, and pervasive Internet;
- Specialized handling of data, through novel datacenter applications (search, data mining etc.)
- Flow-based, controlled capacity and delay for growing multimedia applications.
- Privacy issues, with an Internet that can track citizens' behavior even more aggressively than seen today with social networks, even surveillance between nations becomes more relevant;
- A more democratic Internet in the sense that, potentially, more could conceive and deploy new network services at the core of the network;

- Reduce complexity of the networking protocol ecosystem: Complexity impacts virtually all other problems (security, scalability, resiliency, agility, performance, programmability, autonomic management, etc..), making them harder to solve and limiting the potential impact of solutions to these problems.