Information-Centric Networking
– A position paper –

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The development of Information-Centric Networking (ICN) concepts is one of the significant results of different international Future Internet research activities. In such approaches, the principal paradigm is not end-to-end communication between hosts – as in the current Internet architecture. Instead, an increasing demand for highly scalable and efficient distribution of content has motivated the development of architectures that focus on information objects, their properties, and receiver interest in the network to achieve efficient and reliable distribution of such objects. Corresponding network architectures can leverage in-network storage, multiparty communication through replication and interaction models such as publish-subscribe to provide general platforms for communication services that are today only available in dedicated systems such as peer-to-peer overlays and proprietary content-distribution networks.

Current technologies are in contrast based on a device-centric paradigm, focusing on the interconnection of devices, such as computers, mobile devices, servers, and routers. The communicated information, for instance web pages, music, videos, or computer software, is largely anonymous when transferred over the network. This anonymity makes efficient information distribution hard; it is often solved in overlays on the network infrastructure. In a network based on the information-centric paradigm, the information objects are first-class citizens with unique identity independent of the device they are stored on. This approach enables efficient and application-independent information caching by the network infrastructure, and thus allows large-scale information distribution without violating basic assumptions or resorting to special tweaks or add-ons.

Current State of Information-Centric Networking

The information-centric approach to the network of the future is currently being explored by a number of research projects, both in Europe (PSIRP, 4WARD) and in the US (CCN). At the same time, the Delay Tolerant Networking (DTN) community has developed a message-oriented architecture that has been used along with information-centric addressing and routing concepts. While these approaches differ with respect to their specific architecture, they share some assumptions, objectives and certain structuring architectural properties. In general, the aim is to develop network architectures that are better suited for content distribution (the currently prevailing usage of communication networks) and that better cope with disconnections, disruptions, and flash-crowd effects in the communication service.

The research work in the different initiatives has now led to first results in terms of architecture definitions, implementations, and evaluation work. The acknowledged importance of ICN has led to a formation of new research initiatives such as the newly started EU FP7 project SAIL (Scalable and Adaptable Internet Solutions – http://www.sail-project.eu/) and the NSF-funded project NDN (Named Data Networking – http://named-data.net/).
ICN Research Topics

1) Naming and Addressing
With respect to naming/addressing, the most important question is how to devise a naming/addressing architecture that allows identifying named content globally, provides efficient lookup, is scalable to billions of objects, and is able to deal with node and information object mobility. Previous research in the locator/identifier-split domain has led to flat namespace and DHT-based lookup concepts that have been adopted by some efforts such as the 4WARD project. Other approaches such as CCN are based on hierarchical naming schemes and aggregation of name prefixes as an answer to scalability requirements. The main research question is hence to decide between and align flat and hierarchical name spaces.

2) Efficiency and Robustness
For efficient content distribution, most approaches so far have tried to follow a publish/subscribe-inspired approach, where content gets forwarded and cached along the paths of earlier subscription request. One of the current questions is how this can be merged with CDN-like approaches such as pro-actively distributing content to interest regions. The in-network caching concepts also incur new challenges for resource management. Instead of administratively configured cache management as done in some CDNs, ICN should self-manage resources for ubiquitous in-network caching.

Mobility in ICNs has different properties compared to host-centric networking. To some degree mobility and multi-interface access is naturally supported by the ICN concept as nodes do not rely on maintaining end-to-end paths but can instead leverage in-network caches on every network they attach to. On the other hand, mobility is a challenge in two perspectives: 1) it may introduce frequent changes to the name database and 2) it can introduce delays and disruption to the content delivery process. One of the interesting questions is how current distribution approaches (such as Pub/Sub-based distribution) can cope with such mobility challenges and whether Delay-Tolerant-Networking concepts such as DTN-routing and re-active bundle fragmentation can be employed.

Most ICN variants do not address bandwidth sharing. Proposing models that capture the interplay between in-network caching and bandwidth sharing are important, notably for the purpose of network and cache dimensioning. The way bandwidth should be shared between contending information flows is an open problem that raises a number of challenging questions related to efficiency and fairness.

3) Applications & APIs
Introducing a new information-centric network architecture can enable new types of applications that were too complex to create/operate/deploy/maintain in traditional networks. Much functionality of today’s P2P networks, e.g. caching and simultaneous retrieval from multiple sources, will be inherent to an information-centric network. The ICN API should thus be designed in a way that today’s applications and services could be simplified when run on top of an ICN.

4) Socio-economic aspects
Rethinking business models in the context of ICN is an interesting and important topic. The viability of the current Internet economic model is increasingly called into question, as ISPs claim that retail prices are not sufficient for covering infrastructure cost, whereas the advertising model for some major over-the-top players seems not profitable due to huge bandwidth and storage expenditures. Some proposals for ICN depart from traditional Internet concepts in two ways: 1) they are receiver-oriented and 2) forward and reverse paths may be asymmetrical. Both features may greatly impact business models for information transport, notably interconnection models between network/content/service providers, with a shared incentive for in-network caching.

This presentation provides a solid motivation for ICN, based on concrete scenarios, describes the outcome of the main research activities in the field so far, addressing the mentioned research topics, and reports on objectives and first results of the newly started SAIL project and its Network of Information activity.