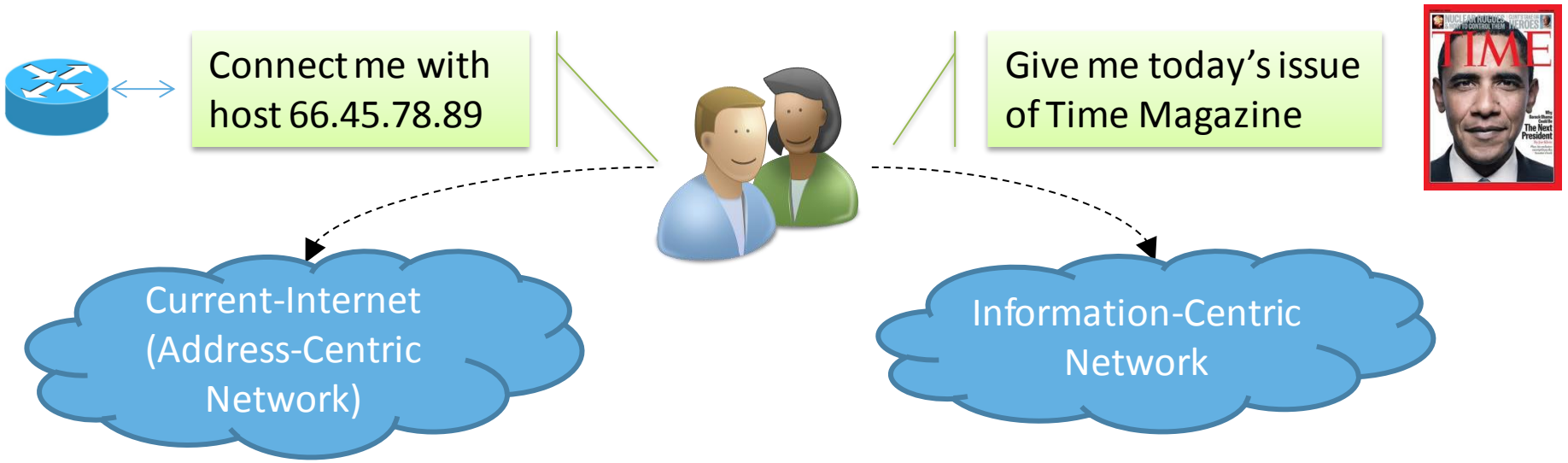

# Information Centric Networking: Changing the Internet from Within?

Nicola Blefari Melazzi
e-mail: blefari@uniroma2.it
http://blefari.eln.uniroma2.it/
+39 06 7259 7501

# Information Centric Network

- The network layer provides users with contents, instead of providing communication channels between hosts, and is aware of content identifiers



# Basic network functions

- Basic functions:
  - address contents, adopting an addressing scheme based on names (identifiers), which do not include references to their location
  - route a user request, which includes a “destination” content-name, toward the “closest” copy of the content with such a name; this copy could be stored in the original server, in a cache contained in a network node or even in another user’s device
  - deliver back the content to the requesting host

# ICN research

- Workshops
  - IEEE NOMEN 2012, 2013
  - ACM SIGCOMM 2011, 2012, 2013 (ICN-2014 will be a full conference)
- Tens of papers in journals and general conferences
- Special issues (Computer Networks in press, Computer Communications in press, IEEE Networks, cfp)
- Standardization: IRTF Information-Centric Networking Research Group (ICNRG)
- Projects
  - TRIAD, DONA, PSIRP, 4WARD, COMET, COAST, CONVERGENCE, SAIL, NDN, PURSUIT, MobilityFirst, **GREENICN**

# ICN research

- Surveys
  - J. Choi et al. “Survey on content oriented networking for efficient content delivery,” IEEE Communications, 2011
  - M.F. Bari et al. “A survey of naming and routing in information-centric networks”, IEEE Communications Magazine, 2012
  - B. Ahlgren et al. “A survey of Information-Centric Networking”, IEEE Communications Magazine, 2012
  - G. Carofiglio et al. “From content delivery today to information centric networking”, Computer Networks, 2013, in press
  - G. Xylomenos et al (G. Polyzos), “A survey of information-centric networking research”, IEEE Communications Surveys and Tutorials, 2013, in press (electronic version available)
    - comparison of seven architectures
    - main alternatives for routing and forwarding: NDN/CCN vs. PSIRP/PURSUIT

# Why do we want ICN?

- Wish list (content=Versatile Digital Item, VDI)
  - Create a VDI, defining related licenses and rights
  - Sign and/or encrypt a VDI
  - Publish a VDI
  - Subscribe to a VDI (meeting specified criteria)
  - Search and Retrieve a VDI (metadata ease semantic searches and operation of search engines)
  - Verify the authenticity of a VDI
  - Monitor the use of published VDIs
  - Communicate with owners of VDIs and allow inter-VDIs communications
    - This could make Search Engine un-necessary (MPEG standard)
  - Versioning a VDI and linking it to other VDIs
  - Update a VDI (my CV, parts catalogue)
  - Delete a VDI (digital forgetting and garbage collection)

# Why do we want ICN? Alternatives

1. Different Application-layer data units and applications (specific, proprietary)
2. Different CDNs / middlewares
3. Overlay solutions
4. Current Internet

or

Interfaces

1. A standard unit of distribution and transaction+ a naming scheme
2. Applications/Tools
3. Middleware (complex functions)
   - publish/subscribe for named data
   - search (and semantic search), rights management
   - security and privacy mechanisms
4. Information centric network (simpler functions at line speed)
   - Efficient access to named-data

Middleware+ Network integrated?

PSI?

# Specific advantages of ICN

- Efficient content-routing
  - Content Delivery Networks (CDNs) offer a similar functionality but they cannot use network resources in an optimal way because they operate over-the-top (and do not have information on other CDNs and on the network status)
- In-network caching
  - off-the-shelf HTTP transparent proxies require stateful operations
  - CDNs are for pros, they are not “democratic”
- Simplified handling of mobile and multicast communication
  - simplifying handovers and stateful nodes
  - enabling de-centralized mobile network architectures

# Specific advantages of ICN

- Simplified support for time/space-decoupled communications
  - **fragmented networks, or sets of devices disconnected from the rest of the 'network' (e.g. IoT, sensors)**
- Simplified support for peer-to-peer communications
  - without the need of overlay dedicated systems
- Content-oriented security model
  - securing the content itself, instead of securing the communications channels
- Per-content quality of service differentiation and traffic engineering
  - without deep packet inspection

# Specific advantages of ICN

- Content-oriented access control
  - access to content as a function of time, place (e.g., country), or profile of user requesting the item
  - access revocation (also known as digital forgetting), so that content may be removed from the system by its creator
  - garbage collection, deleting from the network obsolete contents
- Content-oriented quality of service differentiation
- Create, deliver and consume contents in a modular and personalized way
- Network awareness of transferred content
- Inter-content communications

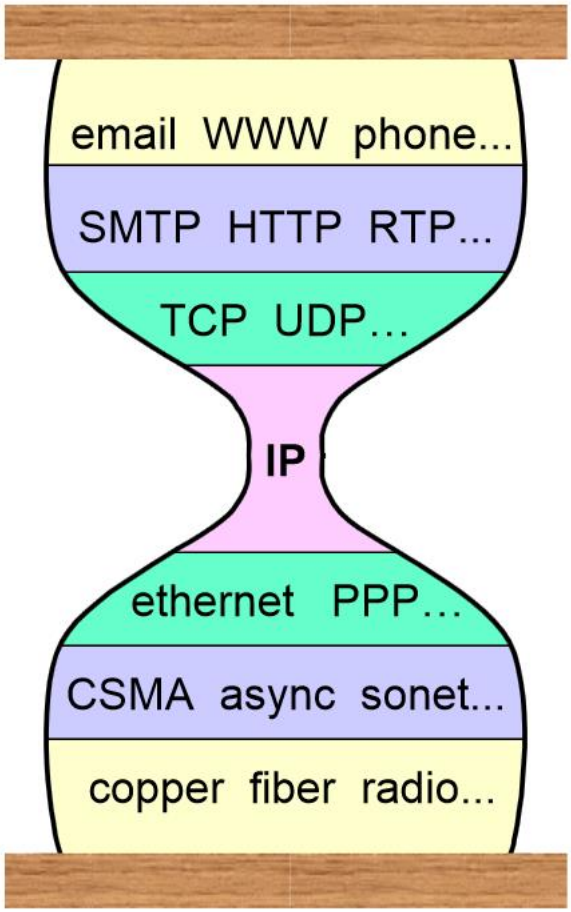
# Key conceptual advantages of ICN

1. Simplification of network design, operation and management
   - Currently, content and service providers have to “patch” shortcomings and deficiencies of IP data delivery by using several “extra-IP” functionalities, such as HTTP proxies, CDNs, multi-homing and intra-domain multicast delivery, to name a few
     - e.g. try implementing pub/sub over CCN wrt over IP

2. Inter-content communications (and bi-directional links)
   - Instructions manual associated with a mobile phone
   - Glasses with RFID and related VDI
   - Elements of houses and cities, beams, walls, doors, bridges, railways talking to persons in disaster scenarios
   - Inter-things communications with pub/sub

# Disadvantages

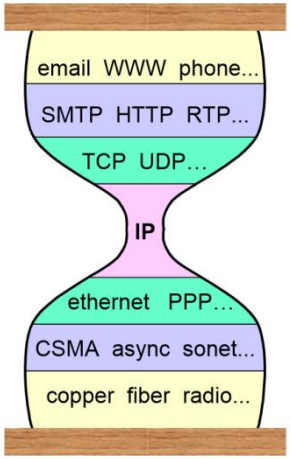
- Scalability concerns
  - number of different contents and corresponding names much bigger than number of host addresses
  - bidirectional communications (reverse paths) require maintaining states in network nodes or using source routing
- Cumbersome support for "conversational" communication patterns and push services
- Changes in the Internet thin waist (IP)




By Steve Deering, 2001

# Internet thin waist (of the protocol hourglass)

- The Internet **is** changing: we enjoy new services and perceive better performance every day
  - innovations are introduced over the top
    - the application layer, defined in software, is flexible
  - new technologies are improving performance from the bottom
    - In some cases in SW
  - but the very heart of the Internet is old and difficult to change
    - intermediate layers are rigid and monolithic
- Internet: fragmented, over-layered, ossified
    - RSVP/DiffServ, mobile IP, multicast
    - entropy , decay, IP-over-IP, patches, stopgap solutions

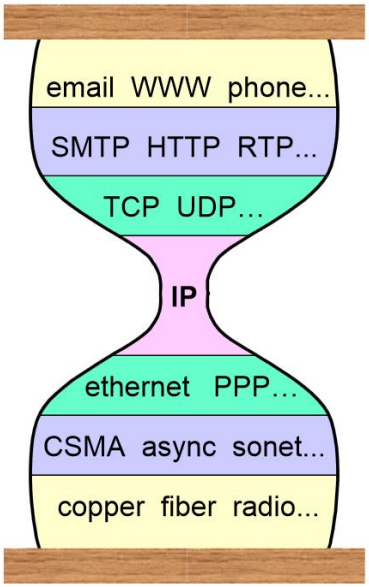



S. Akhshabi, C. Dovrolis: "The Evolution of Layered Protocol Stacks Leads to an Hourglass-Shaped Architecture", SIGCOMM'11, August 15–19, 2011

# High-level TO DO list

1. Business models / Scenarios

2. Internet thin waist
   a) ICN as a networking solution (“replacement” of IP)
   b) over IP, no networking
      - Leading to “Big/Universal CDN“?
        - Caching
        - Replication
        - Multicast
   c) HTTP as the new thin waist (Popa, Ghodsi, Stoica)



# High-level TO DO list

3. Static content retrieval, pull
   - CCN=interest+data (pull)
   - PSI=DHT+topology manager+source routing (forward, collects return path)

# High-level TO DO list

4. Real time communications (e.g. phone call), dynamic content, support of legacy (IP) services, P2P, Pub/Sub?
   - Push services
     - PSI: requires a “session (forward ident)”, off-path, (mobility?)
     - CCN: how to do it with location-independent names (mobility?), scalable & secure way (#entries x updates - who can modify the routing plane?)
     - Polling: 1 week before? Mixed push/pull with interposing server
   - Rekhter's Law (RFC 4984): "Addressing can follow topology (location dependent, IP) or topology can follow addressing (DHT+path stretch or DHT+”session”). Choose one.“
     - Location-Identifier split
     - Multi-component naming: identifier-locator-descriptor-security/trust validator
   - Homogeneous devices (all routers are created equal)

# High-level TO DO list

5. Deployment/Implementation
   - Reasons for current rigidity (if not thin waist)
     - lack of a clear separation between user and control plane, which is not true to the ISO/OSI philosophy
     - proprietary, special purpose and vertically integrated network devices
   - Solutions
     - Software Defined Networking –SDN
       - an architecture characterized by a logically centralized control plane and a well-defined separation between user and control planes (+abstractions)
     - Network Functions Virtualization –NFV
       - Deploy network functions as software components running on industry-standard commodity hardware, instead of specialized hardware

- new ideas will not necessarily remain a dead letter just because “we cannot change the whole Internet”
- networking as a discipline as opposed to a craftwork

# Specific TO DO list

- Primitives & interfaces, protocol architecture
  - Middleware? What functionality at the network layer?
- The naming scheme
  - it specifies the identifiers for the contents addressed by ICN (usability, scalability and security)
- The forward-by-name (or route-by-name) mechanism
  - it relays an incoming content request to an output interface (“name-based” forwarding table)
- The routing protocols
  - used to disseminate information about location of contents, so as to properly setup the name-based forwarding tables
- The data forwarding mechanism
  - it sends the content back to the device that issued a content request
  - it cannot use the forward-by-name mechanisms, because, typically, devices/interfaces are not addressed by the content routing plane

# Specific TO DO list

- In-network caching
  - caching data and replying to incoming content requests
- Segmentation & transport mechanisms
  - splitting a content in different chunks
  - reliable transfer and congestion control
- Security & privacy issues
  - providing content authenticity, protecting the network from fake content, which could also pollute network caches
  - guaranteeing that content be accessed only by intended end users
  - protecting information consumers from profiling or censorship of their requests
- Resilience against fragmentation of the network. Time/space-decoupled communications
- Energy efficient operation
- ICN aware applications (e.g. video distribution - DASH)

# GreenICN Project

- GreenICN: Architecture and Applications of Green Information Centric Networking
- Duration: 3 years (1 Apr 2013 – 31 Mar 2016)
- Website: http://www.greenicn.org

EU Coordinator:
Prof. Xiaoming Fu
University of Göttingen
Germany

JP Coordinator:
Mr. Shigehiro Ano
KDDI R&D Labs
Japan

# GreenICN Project Consortium

## European Partners

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

EU Coordinator

Georg-August-Universität Göttingen (UGO, Germany)

**Contact:** Xiaoming Fu <fu@cs.uni-goettingen.de>

NEC Europe Ltd. (NEE, UK)

CEDEO (CED, Italy)

Telekomunikacja Polska (Orange Labs, Poland)

University College London (UCL, UK)

## Japanese Partners

KDDI R&D LABS

JP Coordinator

KDDI R&D Laboratories Inc. (KDD, Saitama)

**Contact:** Shigehiro Ano <ano@kddilabs.jp>

NEC Corporation (NEJ, Tokyo)

Panasonic Advanced Technology Development Co., Ltd

University of Tokyo (UTO, Tokyo)

Waseda University (UWA, Tokyo)

# GreenICN

- Continue R&D on open ICN issues after first wave of projects
- ICN with a green perspective
- Two main scenarios:
  - disaster recovery (fragmented networks)
  - video delivery

# GreenICN requirements

- Requirement 1: 20% Reduction of Power Consumption of GreenICN for Normal Days
  - EU announced that the total energy consumption of all EU countries should be decreased by 20%
  - Japan announced a reduction of energy consumption of 30% by 2030, compared to that in 2003
- Requirement 2: At Least 40% Reduction of Power Consumption of GreenICN (including end-user devices) for Disasters
  - In 2011, people in Tohoku area suffered 3 days of blackout because of the East Japan Earthquake
  - The 40% reduction aims to make the communication services and related base stations able to operate 3 days in such a scenario

# GreenICN requirements

- Requirement 3: Seamless Services before and after a Disaster
  - The lesson learned at the 2011 East Japan Earthquake is that terminals and services specifically designed for disasters were useless, and that people wanted to use the same terminals and services used in their everyday life
- Requirement 4: Migration Path
  - GreenICN should friendly coexist with the current IP network
- Requirement 5: Scalability and size of the served contents and related names
  - GreenICN should be able to serve at least current Web contents with off-the-shelf technology

# Conclusions

- Need of  business/economic analyses and take up chances
- Need of more quantitative analyses
- Need of devising feasible ICN push services
- Need of showing viable deployment paths (incremental)
  - Exploiting SDN/NFV
  - Taking into due account IPv6

➢ ICN as a comprehensive network-layer solution (new thin waist)?

- If not, then ICN will collapse into CDN-interworking and over the top issues
- or HTTP as the narrow waist of the future internet (Popa, Ghodsi, Stoica)

# Selected Publications

- A. Detti, M. Pomposini, N. Blefari-Melazzi, S. Salsano: “Supporting the Web with an Information Centric Network that Routes by Name”, **Computer Networks**.
- N. Blefari-Melazzi, A. Detti, G. Morabito, S. Salsano, L. Veltri: “Information Centric Networking over SDN and OpenFlow: Architectural Aspects and Experiments on the OFELIA Testbed”, **Computer Networks**
- G. Bianchi, A. Caponi, A. Detti, N. Blefari Melazzi: “Check before storing: what is the performance price of content integrity verification in LRU caching?”, ACM SIGCOMM **Computer Communication Review**
- A. Detti, N. Blefari Melazzi, S. Salsano, M. Pomposini: ”CONET: A Content Centric Inter-Networking Architecture”, **ACM SIGCOMM ICN 2011**
- S. Salsano, A. Detti, M. Cancellieri, M. Pomposini, N. Blefari-Melazzi, “Transport-layer issues in Information Centric Networks”, **ACM SIGCOMM ICN 2012**
- A. Detti, B. Ricci, N. Blefari-Melazzi:”Supporting mobile applications with Information Centric Networking: the case of P2P live adaptive video streaming”, **ACM SIGCOMM ICN 2013** (poster)
- A. Detti, M. Pomposini, N. Blefari-Melazzi, S. Salsano, A. Bragagnini, “Offloading cellular networks with Information-Centric Networking: the case of video streaming", **IEEE WoWMoM 2012**
- A. Detti, B. Ricci, N. Blefari-Melazzi: ”Peer-To-Peer Live Adaptive Video Streaming for Information Centric Cellular Networks”, **PIMRC 2013**
- A. Detti, A. Caponi, G. Tropea, G. Bianchi, N. Blefari-Melazzi: ” On the Interplay among Naming, Content Validity and Caching in Information Centric Networks”, **Globecom 2013**

# Thank you
# Questions?


UNIVERSITY OF ROME “TOR VERGATA”
*Department of Electronics Engineering*

Via del Politecnico, 1 - 00133 Rome - Italy

Nicola Blefari Melazzi, Ph. D.

Full Professor of Telecommunications

Chair of the Department of Electronic Engineering

Phone: +39 06 7259 7501
Fax: +39 06 7259 7435

e-mail: blefari@uniroma2.it
http://blefari.eln.uniroma2.it/