# Information-Centric Networking

## clean-slate architecture for the Future Internet


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**…**

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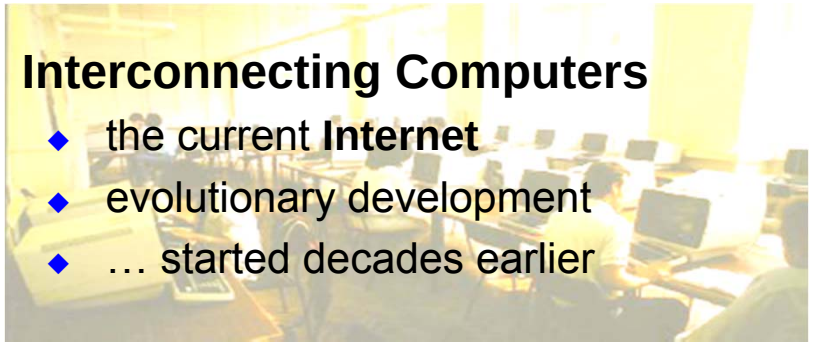
# Motivation

## Clean-Slate Internet Design

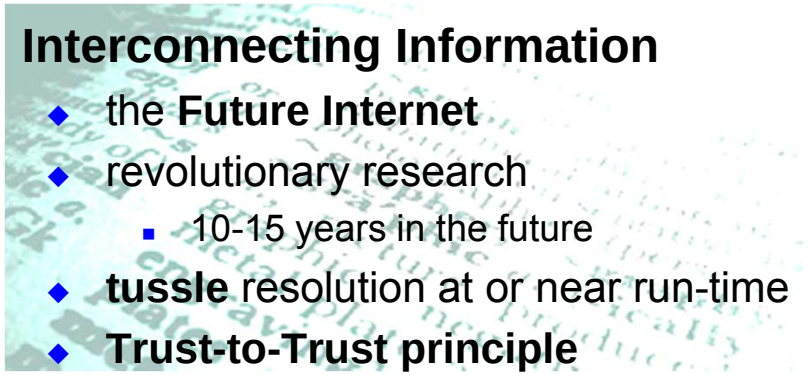
- At the **beginning**…
  - Cooperation/no competition…
  - NO commercial traffic!
  - Endpoint-centric services
- **Now**…
  - Content distribution…
    - >50% of traffic today is video↑
  - Overlays… DPI by ISPs…
  - Trust? Endpoint trust?
    - viruses, phishing, DoS attacks…
  - E2E?
    - NAT, firewalls, middleboxes, CDNs
  - Current net economics favor sender
  - Tussles…
    - e.g.: privacy vs. accountability

## Information-Centric Networking

- **Connecting Wires**
  - the past…



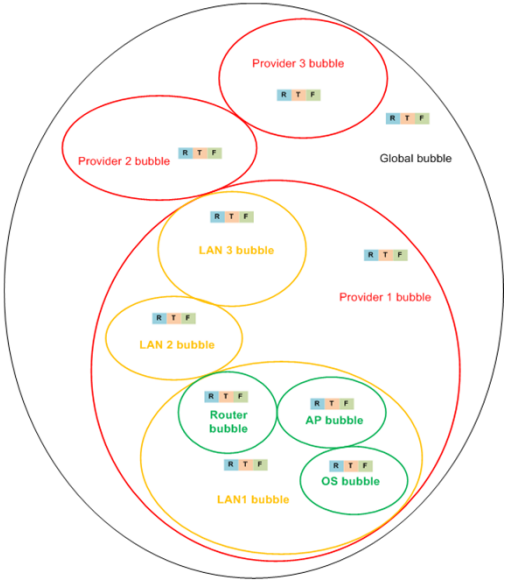
- **Interconnecting Computers**
  - the current **Internet**
  - evolutionary development
  - … started decades earlier

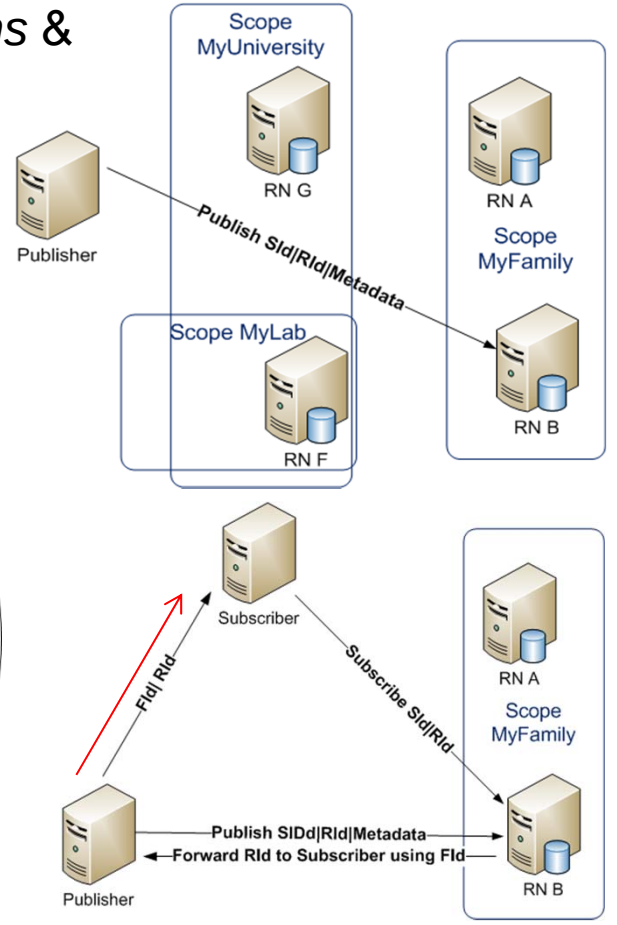


- **Interconnecting Information**
  - the **Future Internet**
  - revolutionary research
    - 10-15 years in the future
  - **tussle** resolution at or near run-time
  - **Trust-to-Trust principle**

# The Publish-Subscribe Internet (PSI) Architecture

- ***Rendezvous***: Matches *publications* with *subscriptions* & initializes the forwarding process
- ***Topology***: Monitors the network & creates information delivery paths
- ***Forwarding***: Implements information delivery
- Applied recursively…
  - local, global rendezvous
  - slow path/fast path rendezvous
- IDs: Rendezvous ID, Scope ID, Forwarding ID…
- **Separation** of functions
- 2 prototype implementations
  - Blackhawk (**PSIRP**)
  - Blackadder (**PURSUIT**)




- N. Fotiou, G.C. Polyzos, D. Trossen, "**Illustrating a Publish-Subscribe Internet Architecture**," ***Telecommunication Systems***, Springer, vol. 52, no. 3, Special Issue on '**Future Internet Services and Architectures: Trends and Visions**,' Online: 23/2/2011.

# Our ICN-related Research Projects

- **PSIRP**: Publish Subscribe Internet Routing Paradigm
  - FP7 ICT STREP, 2008-2010
    - British Telecom (UK)
    - Ericsson (FI & Hungary)
    - Nokia Siemens Networks (FI)



- **PURSUIT**: Publish Subscribe Internet Technologies
  - FP7 ICT STREP, 2010-2013
    - Oy L M Ericsson Ab (Finland)
    - CTVC Ltd (UK)



- **Euro-NF**: Anticipating the Network of the Future—From Theory to Design
  - FP7 ICT NoE, 2008-2012
    - ASPECTS, GOVPIMIT, E-key-nets

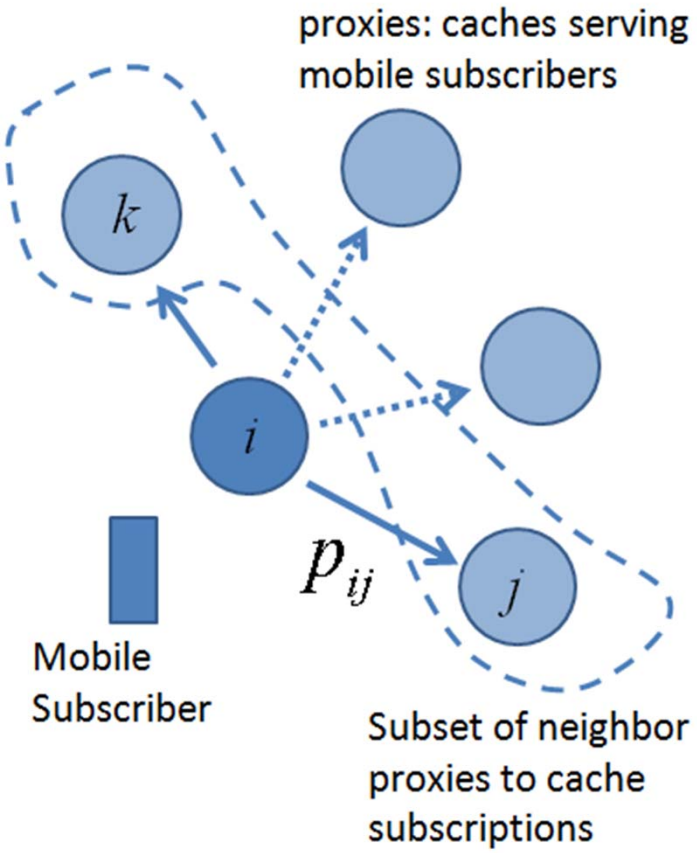

- **EIFFEL**: Evolved Internet Future For European Leadership
  - FP7 ICT SSA, 2008-2010; Think-Tank continues
  - June 2011 TT @ **MIT**: ***Information-Centric Networking***


- ***φSAT***: The Role of Satellites in Future Internet Services
  - ESA (ARTES 1), 2011-2012



# Enhancing Mobility Support in ICN

- **Receiver-driven** and **connectionless pub-sub** can support mobility
- **Mobility** & **user behavior prediction** together with **proactive caching/prefetching** can be used to enhance mobility support
- Effectively **integrate cellular/4G** and **Wi-Fi networks** (**mobile data offloading**)





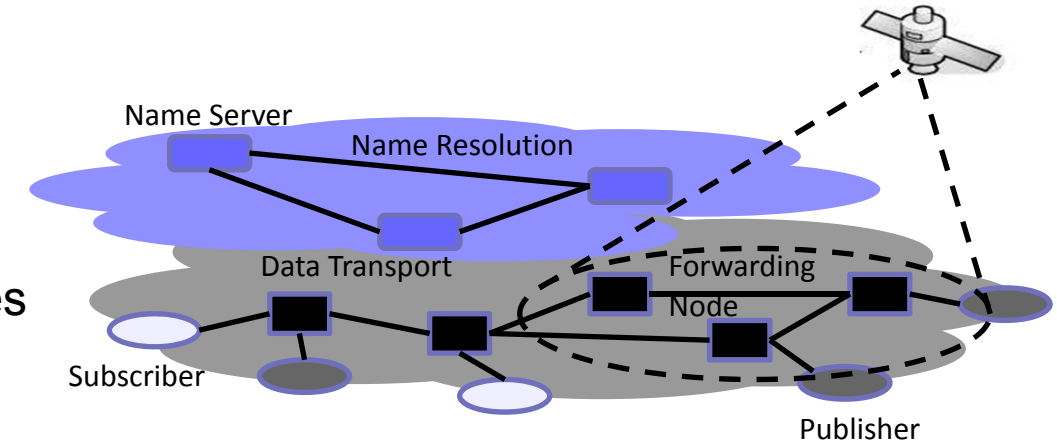
- G. Xylomenos, X. Vasilakos, C. Tsilopoulos, V.A. Siris, G.C. Polyzos, "**Caching and Mobility Support in a Publish-Subscribe Internet Architecture,**" ***IEEE Communications Magazine***, feature topic on '**Information-Centric Networking**,' July 2012 (to appear).
- N. Fotiou, K. Katsaros, G.C. Polyzos, M. Sarela, D. Trossen, G. Xylomenos, "**Handling Mobility in Future Publish-Subscribe Information-Centric Networks**," ***Telecommunication Systems***, Springer, Special Issue on 'Mobility Management in the Future Internet' (to appear).

# Security & Privacy

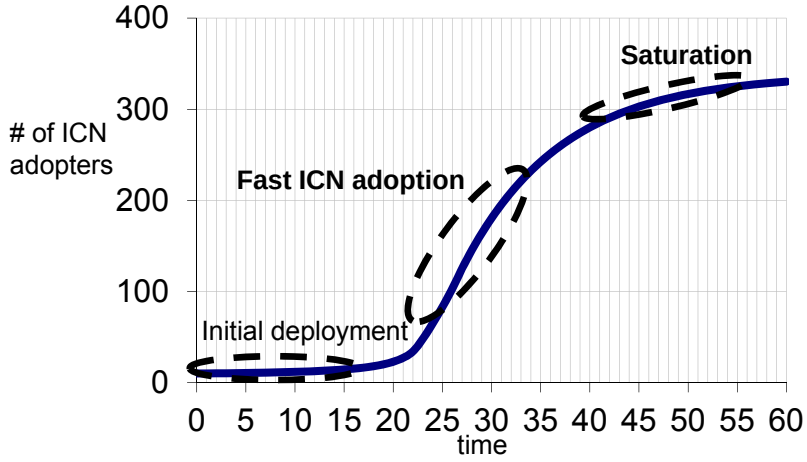
- E2E direct trust not applicable
  - Current Internet does not support it either
  - Socioeconomic trust through mediators (e.g., Rendezvous Providers)
    - D. Lagutin, K. Visala, A. Zahemszky, T. Burbridge, G.F. Marias, "**Roles and Security in a Publish/Subscribe Network Architecture**," Proc. IEEE ISCC 2010, Bologna, Italy, June 2010.
- Users change behavior, content does not
  - Rely on new methods to evaluate content integrity and authenticity
  - Reputable Content
    - N. Fotiou, G.F. Marias, G.C. Polyzos, "**Fighting Spam in Publish/Subscribe Networks Using Information Ranking**," Proc. 6th Conf. on Next Generation Internet (NGI), Paris, France, June 2010. (**Best student paper award**)
- End-user privacy can be effectively supported in ICN (at the internetwork level)
  - Who asks for what content hidden from content provider, caches
  - Pub/Sub matching through *trusted* mediator service (e.g., **Rendezvous** providers)
    - **BUT** privacy from Rendezvous providers becomes more of an issue
- Spam & malicious content distribution is blocked
  - There is no unsolicited traffic in the network!
    - Content is delivered after explicit request
  - New adversary models
    - P. Nikander, G.F. Marias, "**Towards Understanding Pure Publish/Subscribe Cryptographic Protocols**," Cambridge Security Protocols Workshop (SPW), June 2008 .

# φSAT: The role of Satellites in FI Services

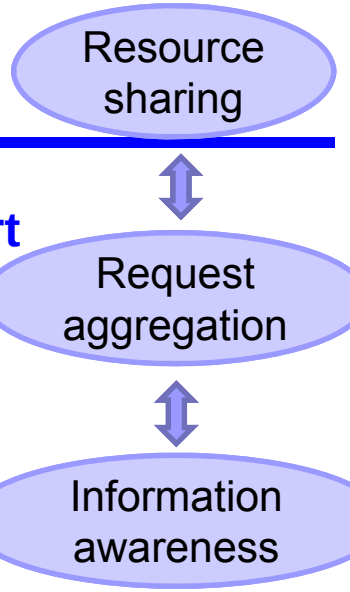
- Aim:
  - To investigate the technical feasibility & business viability of the integration of SatCom with terrestrial ICN architectures
  - Focus on the PSI architecture



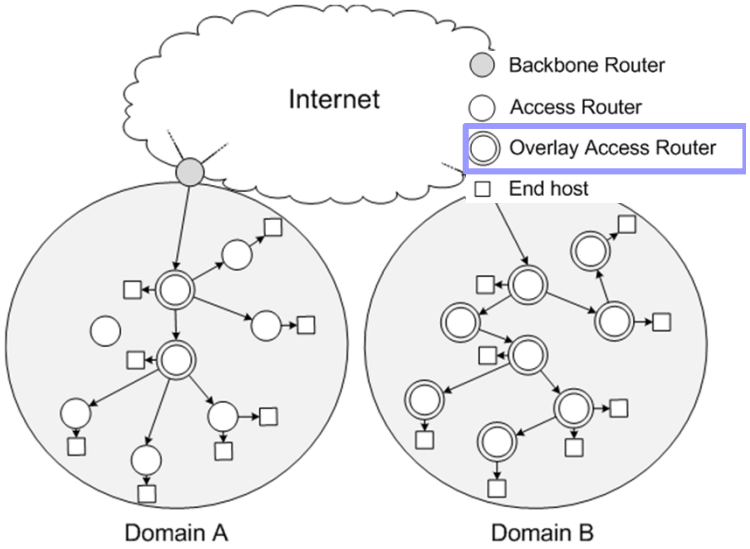

- Early Results
  - Methodology to identify application/service scenarios where the capabilities of SatCom and ICN bring highest techno-economic gains
    - Key **SatCom** capabilities: Broadcast/Multicast, Wide Coverage
    - Key **ICN** capabilities: Data aggregation, Multipath Routing, Mobility Support, In-network Caching
  - Candidate scenarios identified
    - Hybrid Broadcast IPTV
    - M2M Communications
    - 4G Backhauling
  - Socio-economic evaluation
    - Market evolution for each scenario



# MultiCache & H-Pastry



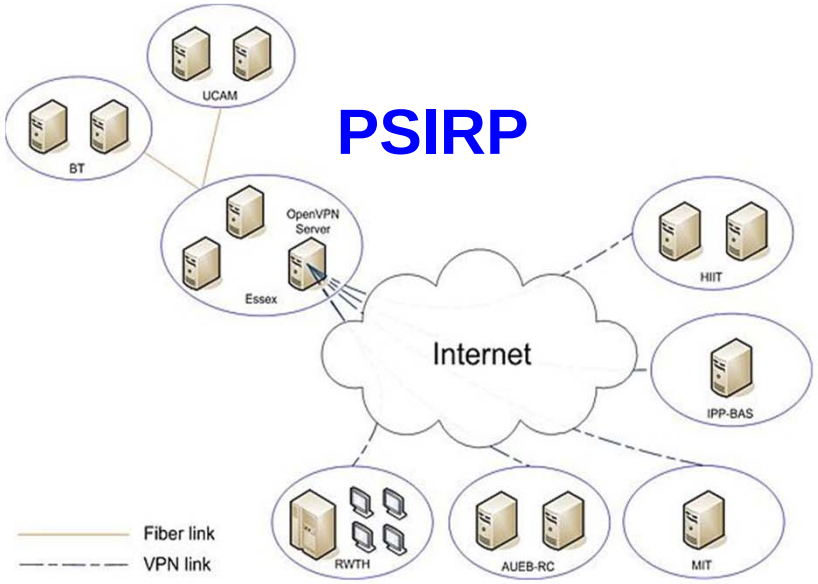

- Overlay architecture for **content distribution** & **mobility support**
  - Based on the joint operation of multicast and caching
  - Head-to-head comparison against BitTorrent
  - ✓ Substantial reduction of inter-domain traffic (↓53%)
  - ✓ Substantial improvement of download times (↓56%)
- Investigated **incremental deployment**
  - Both at the inter-domain and the intra-domain level
  - ✓ Consistent benefits for network operators
  - ✓ Sparse deployments of high storage capacity overlay access routers preferable
- H-Pastry: Canonical version of Pastry
  - Considering proximity metrics & routing preferences
  - ✓ Substantial reduction of stretch (↓ 60%), while constraining traffic within AS boundaries
- Wide-area rendezvous with flat names
  - Based on H-Pastry, comparison with DONA
  - Routing efficiency vs. state and signaling overhead





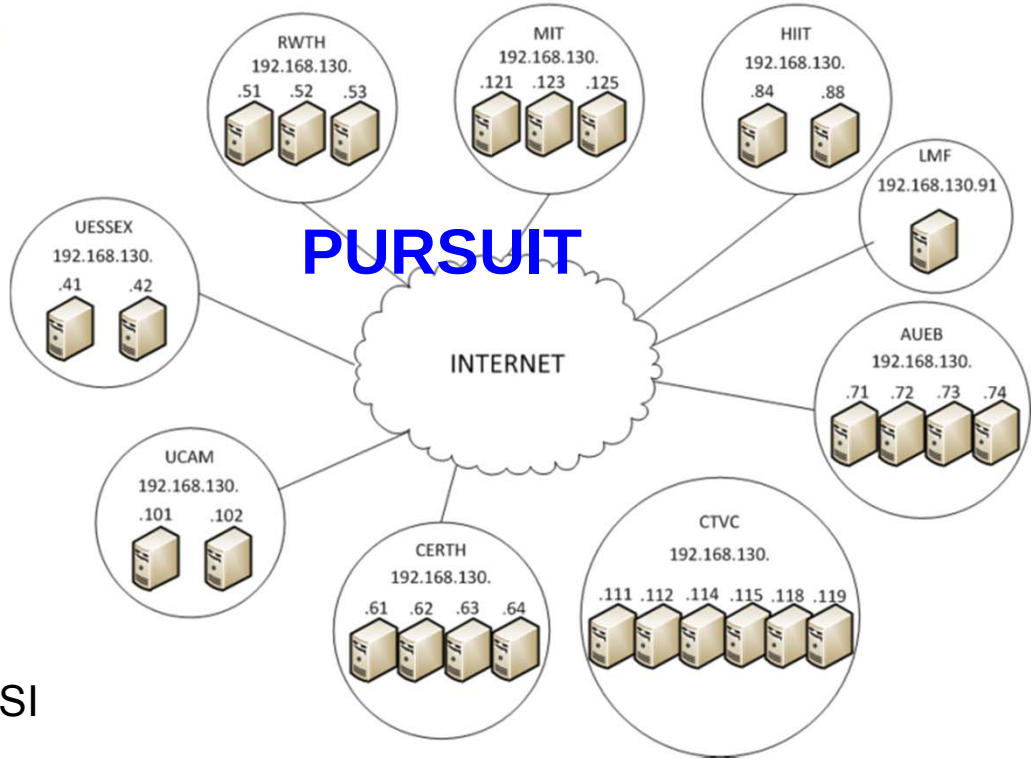
- K.V. Katsaros, G. Xylomenos, G.C. Polyzos, "**MultiCache: an Overlay Architecture for Information-Centric Networking**," ***Computer Networks***, vol. 55, no. 4, Special Issue on '**Architectures and Protocols for the Future Internet**,' March 2011 .
- K.V. Katsaros, N. Fotiou, X. Vasilakos, C.N. Ververidis, C. Tsilopoulos, G. Xylomenos, and G.C. Polyzos, "**On Inter-domain Name Resolution for Information-Centric Networks**," Proc. IFIP Networking, May 2012 (to appear).

# Prototype Implementations & Testbeds




**PSIRP Testbed (w/ Blackhawk)**
- 6 countries: UK, FI, GR, D, BU, US
  - In addition: Belgium during ICT demos
- Tunneled over the public Internet
  - +**dedicated fiber** where available

**PURSUIT Testbed (w/ Blackadder)**
- 25 nodes
- 5 countries: UK, FI, GR, D, US
- Tunneled (VPN)
  - over the public Internet




## Current & future work

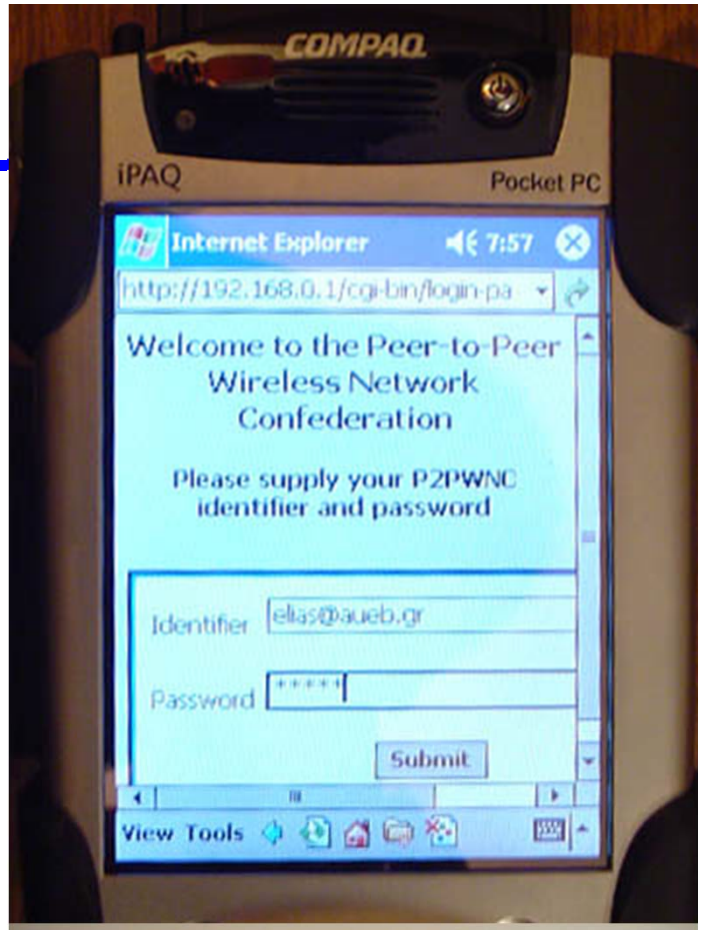
- Socket emulator, multipath transport, voice & multimedia conferencing over PSI
- Wireless/mobile testbed extensions

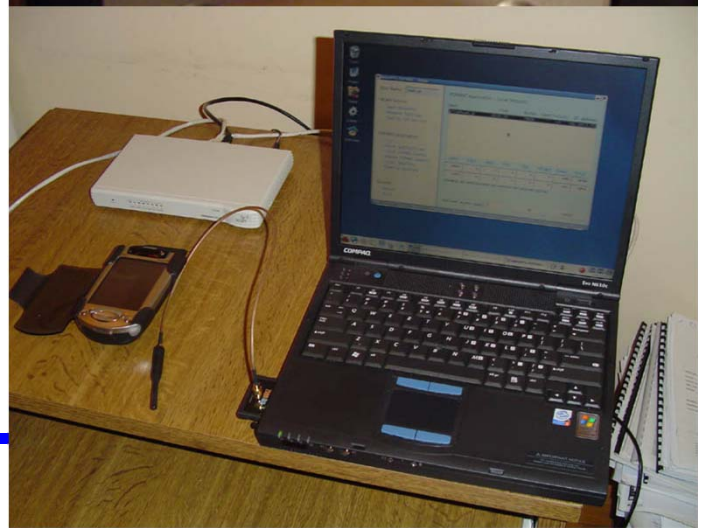
# Conclusion & Notes on ICN Research

- ICN is better positioned to address
  - Content/information distribution, mobility, caching, security...
  - evolution & tussles resolved at or near run-time
- The PSI architecture inherits the advantages of ICN & those of the publish/subscribe paradigm
  - in particular the security ones….
    - but PSI selected and added specific security mechanisms
      - Packet Level Authentication
      - Secure Forwarding (zFilters)
      - Scopes
      - Bubbles
      - Information Ranking
- Many open issues for ICN
  - Global Rendezvous, scalability
  - Transport protocols/techniques, flow/congestion control, etc.

# P2P Wireless Net Confederation

- Embedded Software for Wi-Fi and other Wireless Systems
- Operating on inexpensive home network equipment and mobile phones/PDAs
- Embedded Linux on Access Points
- Open source code available at:
  - http://mm.aueb.gr/research/p2pwnc/
- Based on open protocols
- Strong public key cryptography
  - RSA
  - Elliptic Curve


- E.C. Efstathiou, P.A. Frangoudis, G.C. Polyzos, "**Stimulating Participation in Wireless Community Networks**," Proc. IEEE INFOCOM 2006, Barcelona, Spain, April 2006.
- E.C. Efstathiou, P.A. Frangoudis, G.C. Polyzos, "**Controlled Wi-Fi Sharing in Cities: a Decentralized Approach Relying on Indirect Reciprocity**," ***IEEE Transactions on Mobile Computing***, vol. 9, no. 5, August 2010.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# **ARCHANGEL**: An architecture for ubiquitous, intelligent, transparent activities monitoring for active ageing & independent living

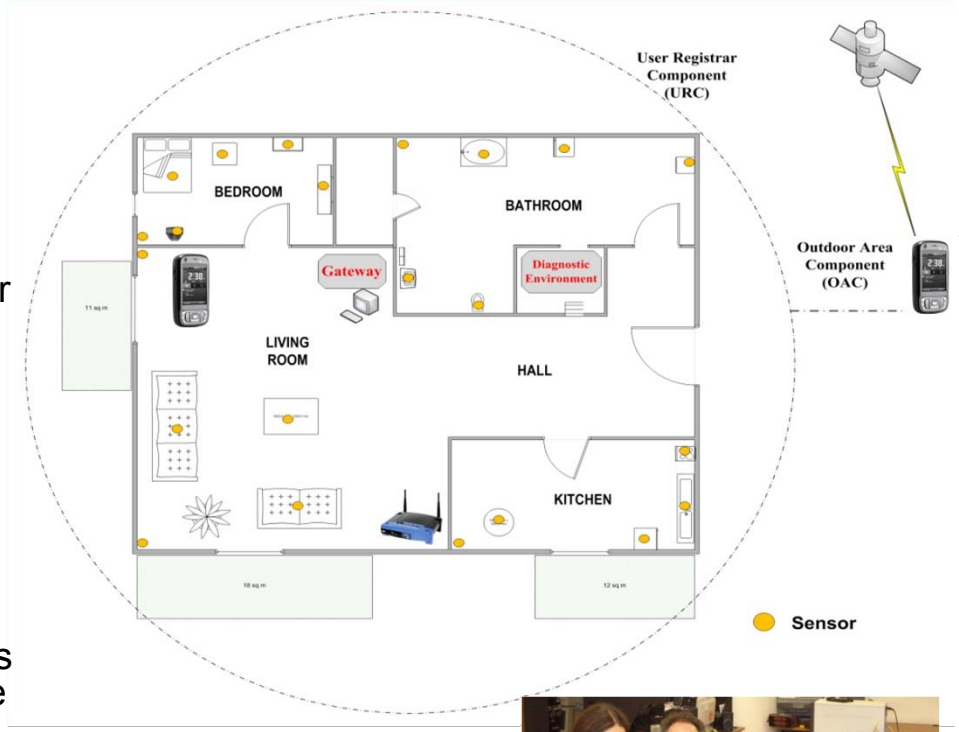
- Funding from **Microsoft Research** through a ***Cell Phone as a Platform for Healthcare* Award**

**Project Highlights**

- **Sensor-based system** for monitoring and modeling the activities of the **elderly** and people with special needs.
- Applies to the **home** life and possibly to the person **outside the home**
- Monitored person caries GPS-enabled cellular phone and/or other localization devices
- Deploy off-the-self sensors to home, other locations

**Objectives**

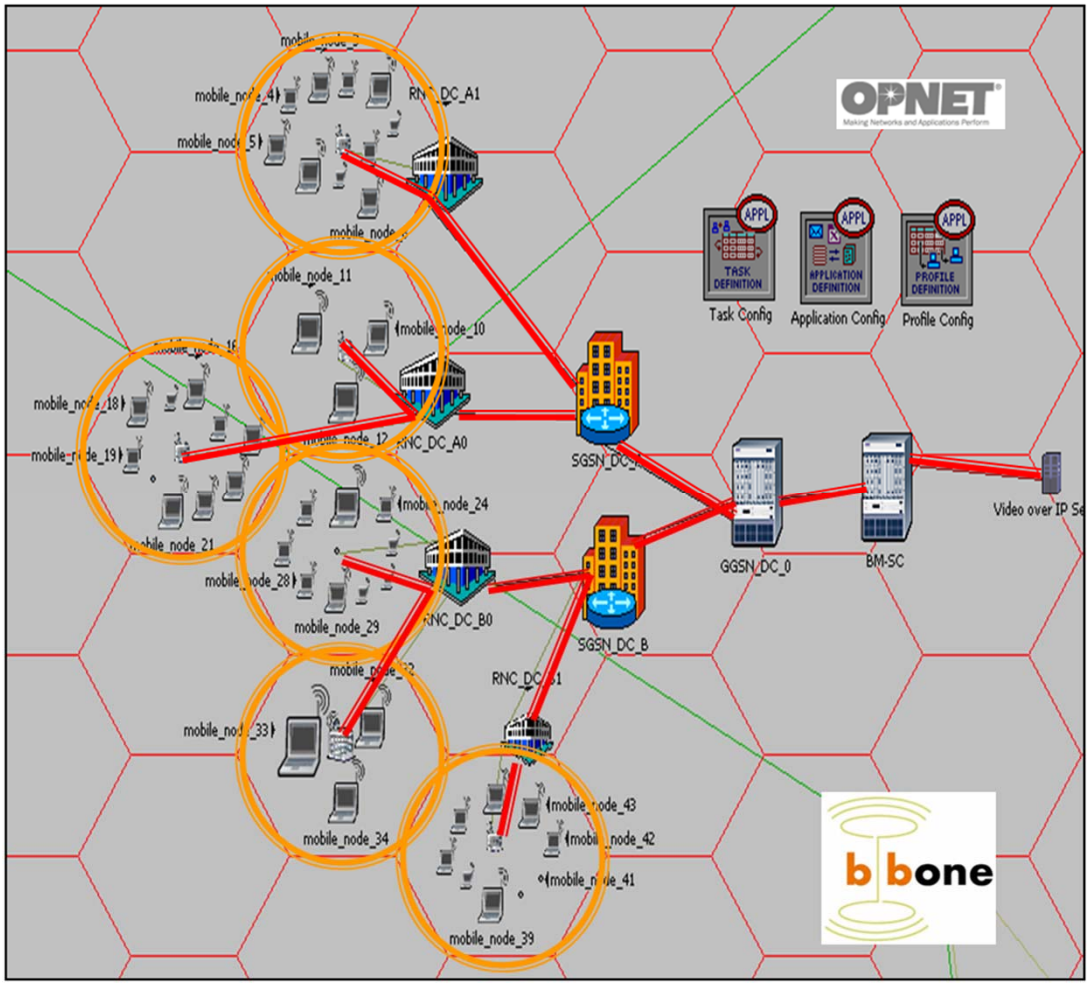
- **Learn the daily activities** of the monitored individuals
- **Detect changes** in individuals' routines and health status
- **Provide alerts** and **preliminary diagnosis** as quickly as possible when something out of the ordinary occurs
- **Actuator-based automation** of certain tasks in the home




➢ G.J. Papamatthaiakis, G. Xylomenos, and G.C. Polyzos "**Monitoring and Modeling Simple Everyday Activities of the Elderly at Home**," Proc. IEEE CCNC, special session on '**Advanced Technologies for Care at Home**,' Las Vegas, NV, January 2010.

# Broadcast and **Multicast** over UMTS (3G)

- the ***B-Bone*** IST project
  (EU funded, FP6, 2004-06)
  - PHY tradeoff: broadcast
    (@ max. power)
    vs. multiple unicasts
    (opt. power control)
  - IP signaling for multicast
    - multimedia
    - levels of quality
    - security
- **Multicast** over 4G
  - 4G: integration of many network technologies:
    - traditional cellular
    - WLANs
    - broadcast nets (DVB-H)
  - multiple providers





- G. Xylomenos, K. Katsaros and V. Tsakanikas. "**Support of multiple content variants in the multimedia broadcast / multicast service**," ***International Journal of Communication Systems***, vol. 24, 2011.
- G. Xylomenos, V. Vogkas and G. Thanos, "**The Multimedia Broadcast/Multicast Service**," ***Wireless Communications and Mobile Computing,*** vol. 8, 2008.

# Other ICN-Relevant Research Projects

- **DONA**
  - flat self-certifying names
  - runs on top of IP
- **CCN/NDN**
  - human readable hierarchical names
  - couples resolution - data transport
  - “runs on top of everything and … everything runs on top of it…”
- **MobilityFirst**
  - named objects can be users, content, services
  - separates names & addresses
- **4WARD/SAIL**
  - flat self-certifying names
  - both coupled & decoupled resolution - data transport
- **CONVERGENCE**
  - objects represented by MPEG-21 based containers
  - CoNET arch. ~ CCN, interfaces/co-exists with IP
- **COMET**
  - flat unique identifiers; supports content scoping & filtering
  - middleware; runs on top of IP
- **HAGGLE**
  - DTN
  - mixed/general naming: ID (flat), but also possibly a "To" field
  - stores fwd state with object