Context-Aware Information Delivery in Assistive Environments over a Publish-Subscribe Internet

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Outline

- **Introduction, motivation, overview**
  - Context-Aware Information Delivery in Assistive Environments
  - ARCHANGEL

- **Information-Centric Networking &**

  The Ψ (PSI) clean-slate Architecture

- **Context-Aware Information Delivery in Assistive Environments over ICN/PSI**

- **Discussion & Conclusion**

The Pervasive Healthcare Paradigm

- Constinuous (medical) supervision of patients
  - or, the general/particular population
  - Aging Well
    - Population is aging in many developed countries

- Advanced electronic healthcare services
  - generation of (multimodal) data
  - anywhere, anytime, for/by anyone

- Data (requirements)
  - acquisition
  - distribution and proper delivery
  - availability
  - security
  - Context Awareness (Adaptivity, Reactiveness, …)

Context Awareness Information Delivery in Assistive Environments

- Information Delivery:
  - Assistive environments have special requirements on content and information presentation
  - Different presentation layers exist
  - Specialized delivery in context of reactive/proactive data transmission
  - The transmitted information usually contains sensitive data that needs to be secured
- Some of the issues can be addressed through Context-Awareness:
  - Capability of the networking applications to be aware of the existence and characteristics of the user's activities and environments
  - Systems have to adapt their behavior based on the current conditions and the dynamicity of the environment
  - *A system is context-aware if it can extract, interpret and use context information and adapt its functionality to the current context of use*

ARCHANGEL

Cell Phone as a Platform for Healthcare Award—Microsoft Research

an ARCHitecture for ubiquitous, intelligent, transparent activities monitoring for active AgeiNG and indEpendent Living through the early detection of signs of medical problems: http://mm.aueb.gr/research/archangel

- Research in innovative ways to advance healthcare services and solutions, as well as to mitigate the growing healthcare concerns

- The aim is to design and implement
  - ◆ a cost-effective, secure, adaptable and interoperable framework for…
  - ◆ learning and monitoring the daily behavior of the elderly
  - ◆ using advanced sensor networking, machine learning, and controlled interaction with caretakers
  - ◆ based on off-the-shelf sensors and positioning-enabled mobile phones
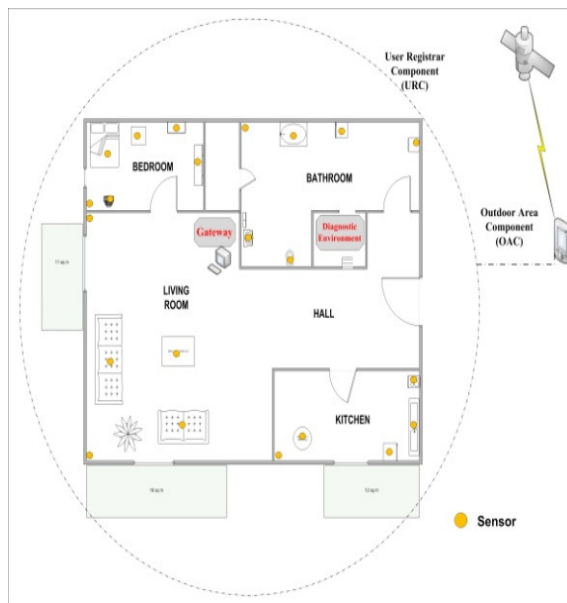
Internet Clean-Slate Design

- What stood at the beginning
  - Collaboration
  - Cooperation
  - NO commercial traffic allowed!

- Endpoint-centric services not enough

- What about:
  - Trust?
  - Legitimacy of E2E?
    - NAT, firewalls, middleboxes
  - Role of overlays?
  - Information centrism?

Clean-slate design…

- Question ALL fundamentals
- Challenge our thinking
- Take nothing for granted, including industry structures
- Clear vision

…with late binding (to reality)

- Consider migration and evolvability in separate work items
  - How to get our design into real deployments, e.g., overlay vs. IP replacement?
- Consider necessary evolution of industry (and regulatory) structures
  - How do industries need to evolve in certain scenarios?

Motivation for an Information-Oriented Architecture

- **End-to-end** communication **is not** the prevailing paradigm
  - Firewalls, NATs, proxy-servers…
  - **Information-centric use** of the Internet (e.g. CDNs, proxy-servers)
  - Overlay content delivery structures ignore
    - network topology & data location
    - Request aggregation hard to achieve without information-awareness!
- Imbalance of power in favor of the sender
  - The network will forward anything a sender will inject
- No trust
  - E.g., phishing, spam, viruses, worms, etc.
- No adequate support for mobility (& multicast)
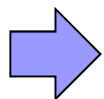
⇨ New ways the Internet is used, for which it was not designed…

Relevant Research Projects

- **PSIRP**: Publish Subscribe Internet Routing Paradigm
  - FP7 ICT STREP, 2008-2010
  - **the basis**
- **PURSUIT**: Publish Subscribe Internet Technologies
  - FP7 ICT STREP, 2010-2013
  - revisiting, extending, above and below the Internet layer
- **φSAT**: The role of Satellite in the Future Internet
  - ESA funded study, 2011-2012
- **Euro-NF**: Anticipating the Network of the Future—From Theory to Design
  - FP7 ICT NoE, 2008-2011+
  - various topics, including network architecture
- **EIFFEL**: FP7 ICT SSA, 2008-2010
  - Think-Tank continues
   - next meeting in June-July 2011 at MIT

Publish Subscribe Internet Vision

- Envision a system that dynamically adapts to evolving concerns and needs of its participating users
  - **information centrism**
- Publish–subscribe based internetworking architecture restores the balance of network economics **incentives between the sender and the receiver**
- Recursive use of publish-subscribe paradigm enables dynamic change of roles between actors

Objectives
- Specify, implement and test an internetworked pub/sub architecture
  - follow a **clean-slate design** approach
- Perform qualitative and quantitative evaluation
  - **Security and socio-economics important!**
  - Migration and incentive scenarios important (e.g., overlay)!
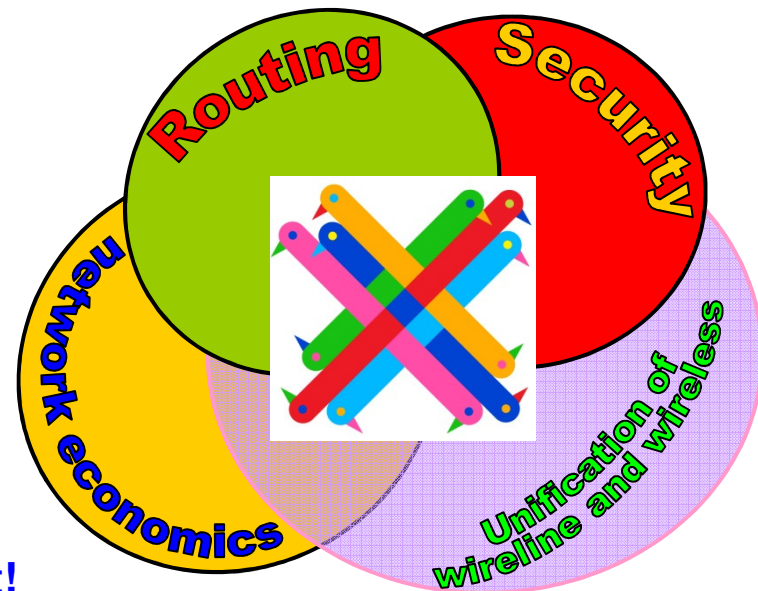
Main Design Principles of the Ψ Architecture

- **Information is multi-hierarchically organised**
  - Higher-level information semantics are constructed in the form of directed acyclic graphs (DAGs), starting with meaningless forwarding labels towards higher level concepts (e.g., ontologies).

- **Information scoping**
  - Mechanisms are provided that allow for limiting the reachability of information to the parties having access to the particular mechanism that implements the scoping.

- **Scoped information neutrality**
  - Within each scope of information, data is only forwarded based on the given (scoped) identifier.

- **The architecture is receiver-driven**
  - No entity shall be delivered data unless it has agreed to receive those beforehand, through appropriate signalling methods.

Information reachability/ scoping

Information Hierarchies

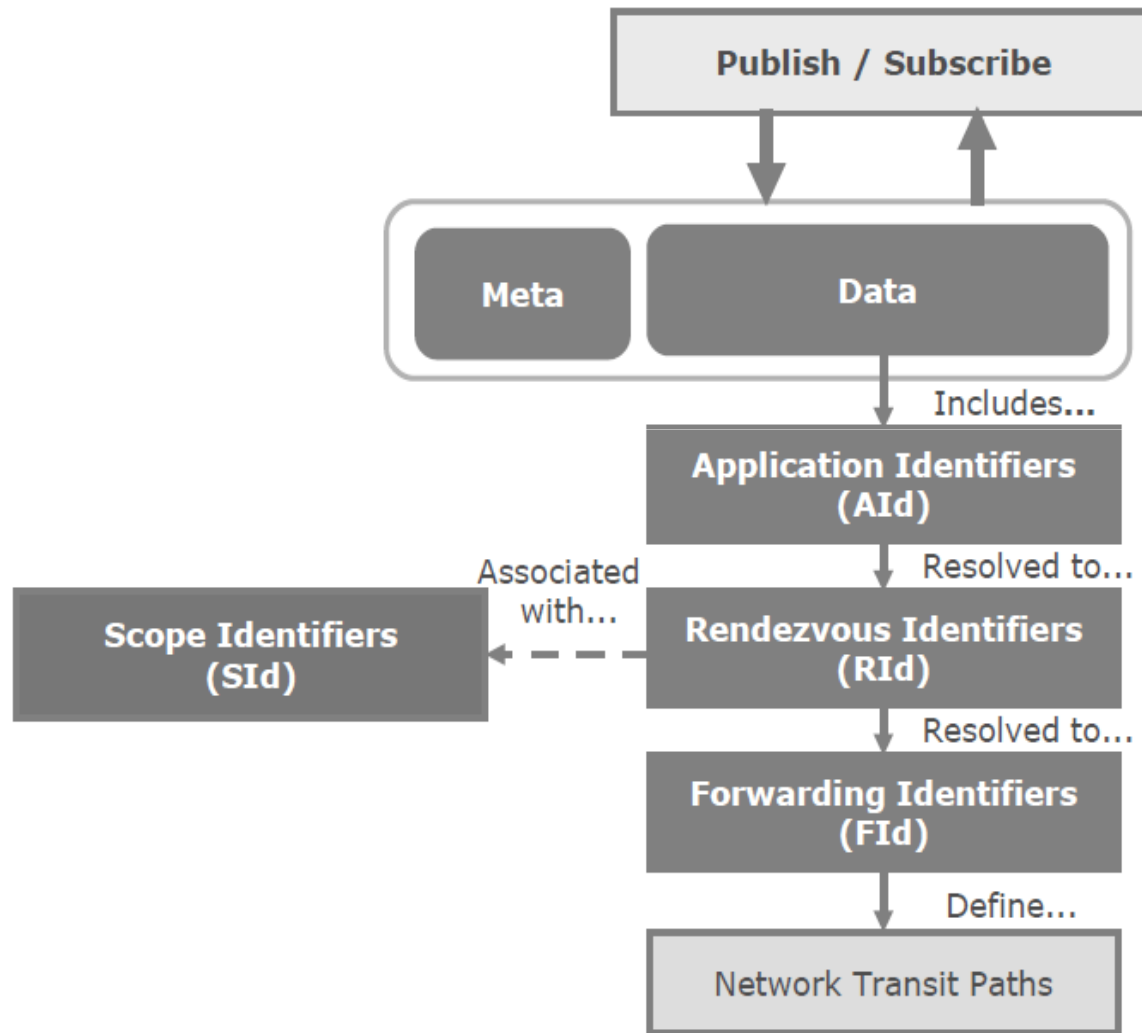**Communication Model**
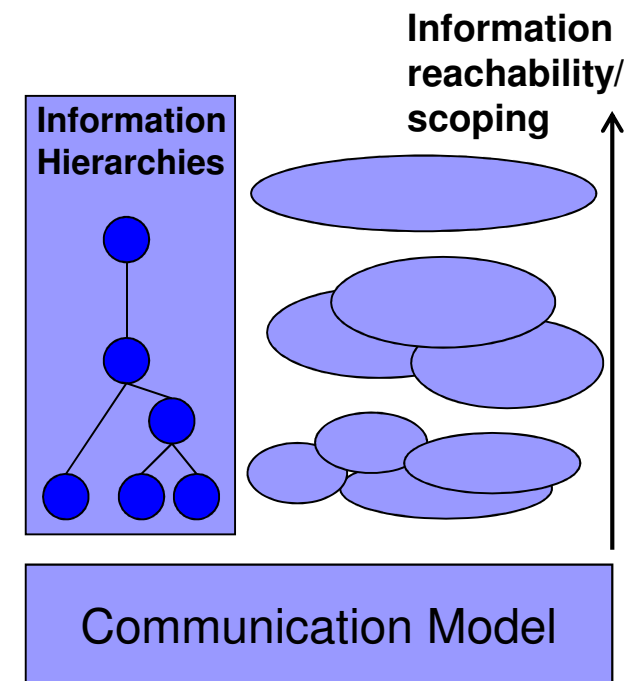
The PSI (Pub/Sub Internet) Architecture

- Ψ
  - Clean-Slate
  - Native

- Two different prototype implementations exist
  - Blackhawk (PSIRP)
  - Blackadder (PURSUIT)
  - More coming up...?

- Overlay implementations
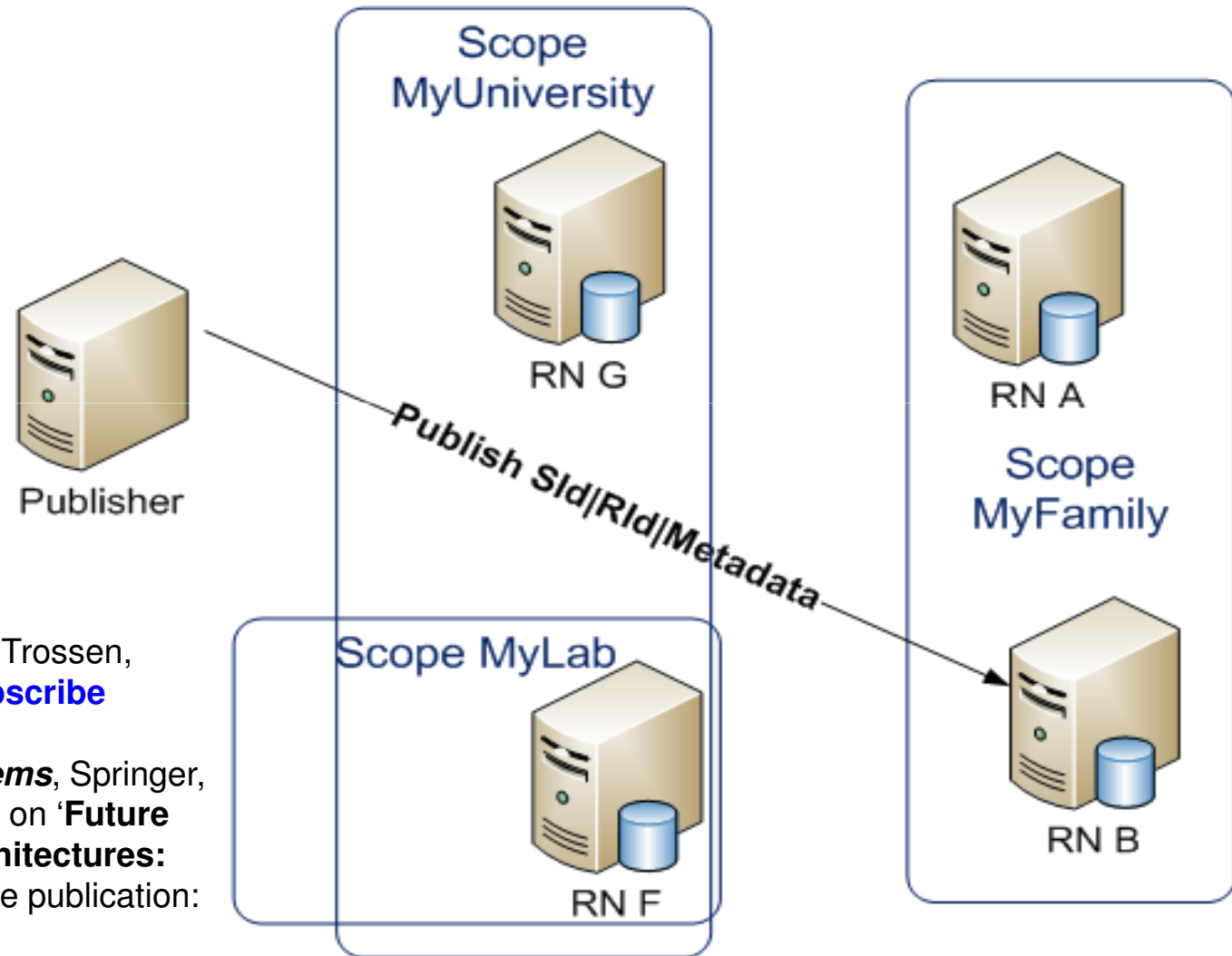- Application/Domain-specific implementation/adoption

Basic Functions

- **R**endezvous: Matches *publications* with *subscriptions* and initializes the forwarding process

- **T**opology: Monitors the network and it creates information delivery paths

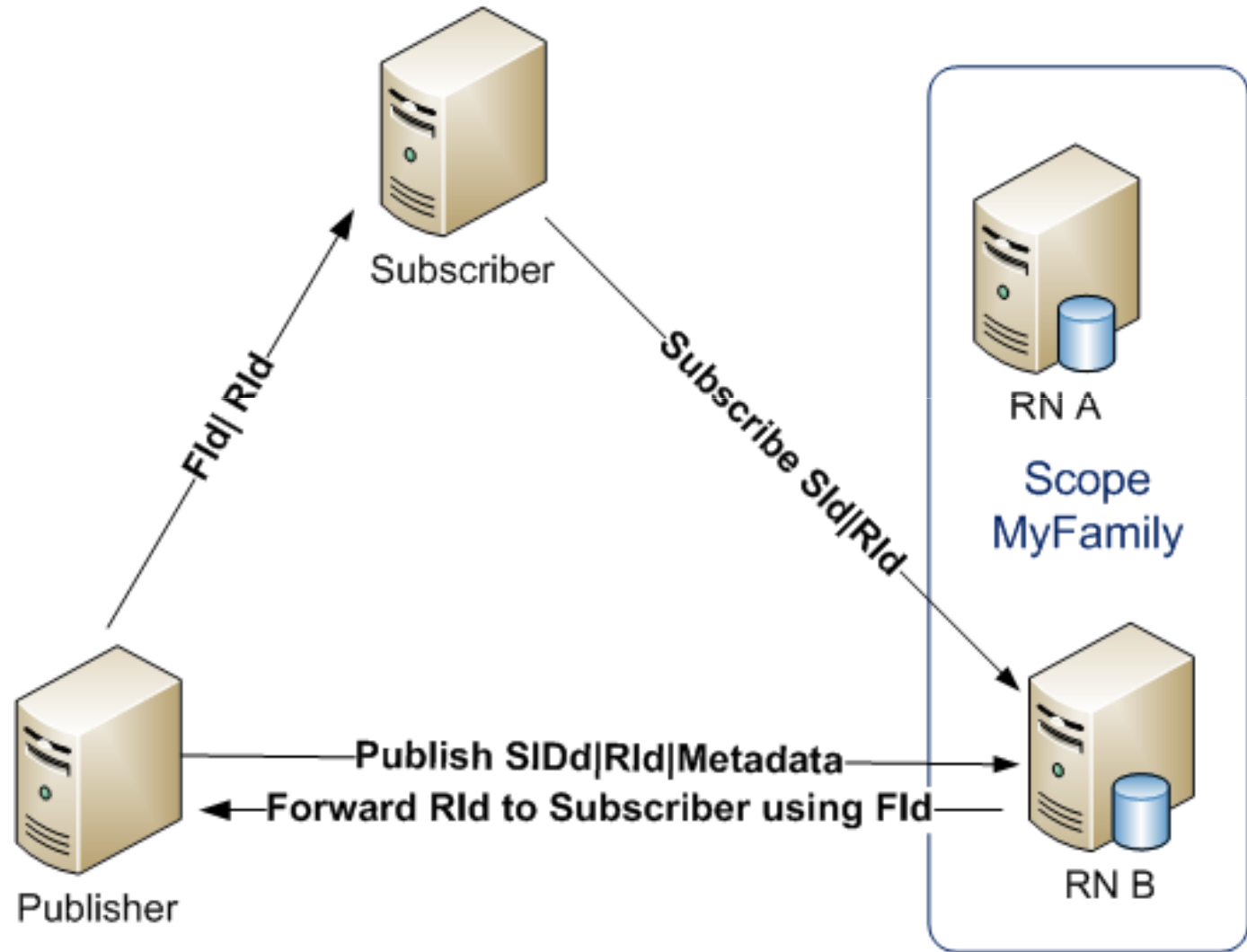- **F**orwarding: Implements information forwarding
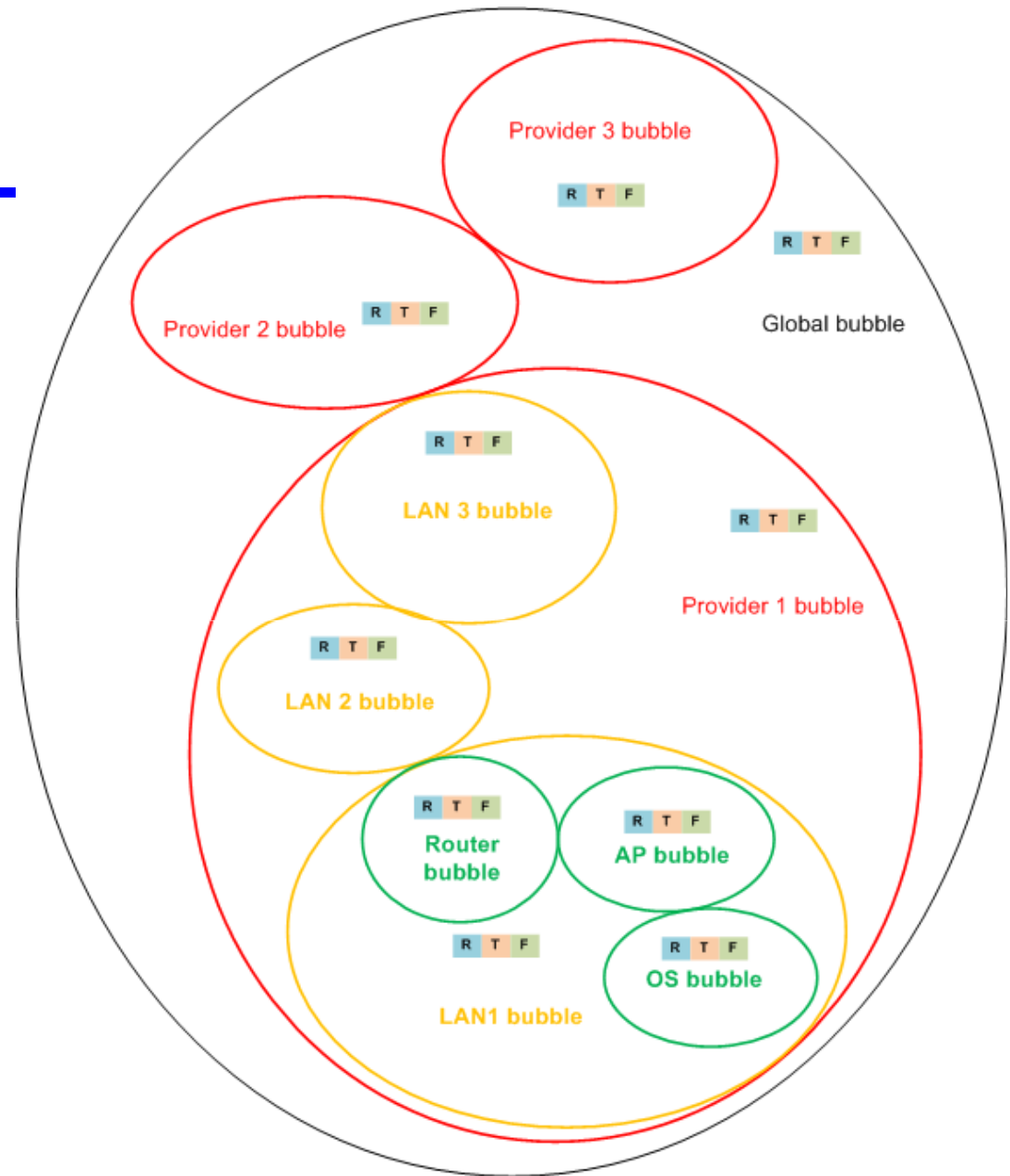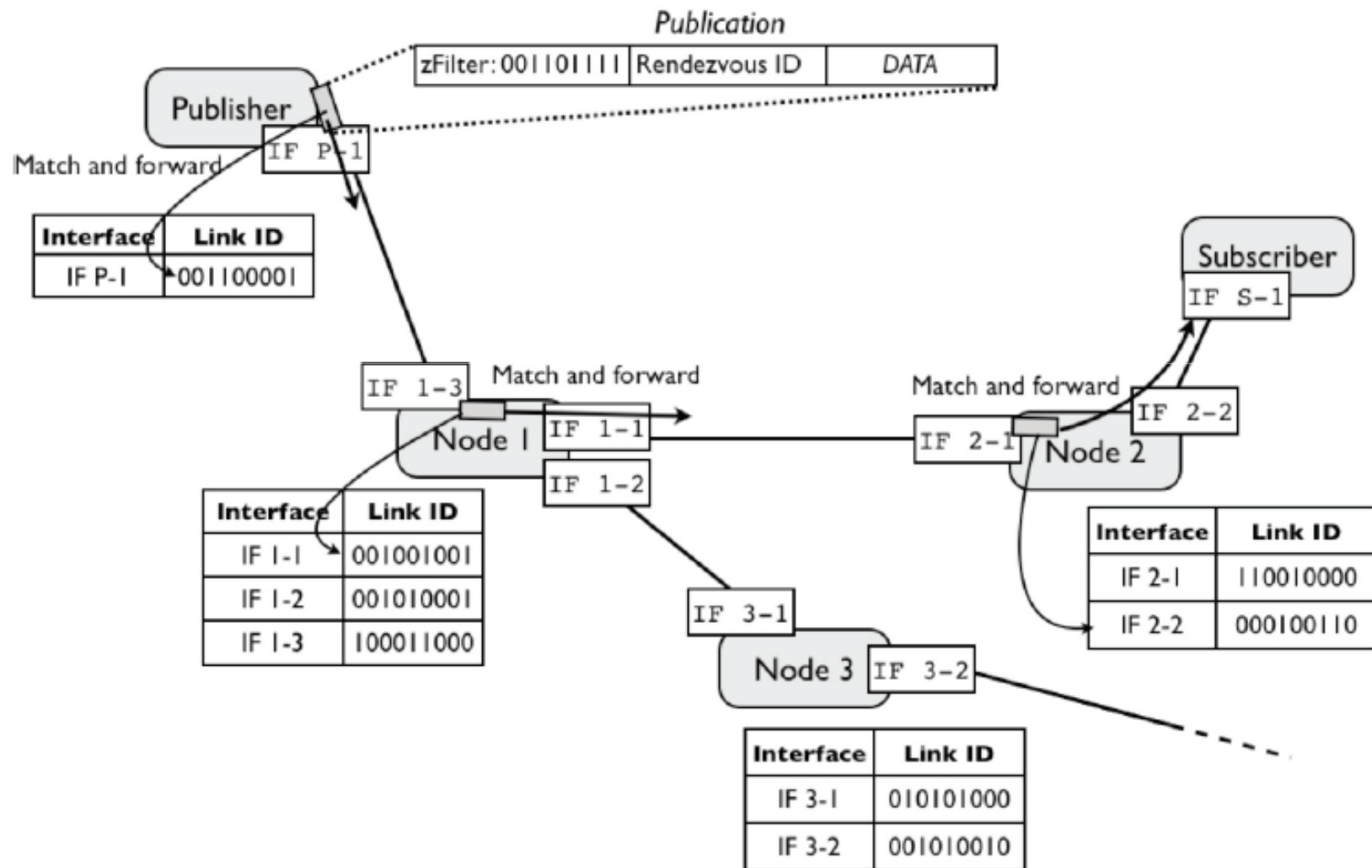
Identifiers

Ψ Publication

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 publication: 23/2/2011.

Ψ Subscription

zFilters Based Forwarding

Security Requirements

- Publications confidentiality
  - publications should be not revealed to unauthorized subscribers
- Subscription confidentiality
  - user subscriptions should be kept secret
- Integrity, Availability
- Authentication, Anonymity
- Accountability
- Information Scoping

Secure Forwarding Mechanism

- Forwarding is based on the creation of a Bloom filter (called zFilter) that contains all the link identifiers through which a packet has to travel

- Link identifiers are unique per information flow

- zFilter creation involves an encryption mechanism

  - DoS attack resistant
  - Almost impossible to
    - redirect an information flow
   - send arbitrary packets to a destination

Security Characteristics of Ψ

- Pub/Sub restores the imbalance of power between sender and receiver(s)
- No information flow until **explicit** signal for
  - Interest for specific piece of information
    - Anti-Spam mechanism
  - Availability of a specific piece of information
    - Anti-DoS mechanism
- Pub/Sub facilitates
  - Anonymity
  - Mobility
  - Multihoming
- Message aggregation
  - Resource sharing (e.g., with multicast)

Scopes: Ψ's Information *Firewalls*

- Scopes allow for information location as well as for control of information dissemination

- Can be physical….
  - ◆ e.g., a sub-network

- … or logical
  - ◆ e.g., my friends in Facebook

- In scopes, access control and accounting mechanism will be implemented

Building Blocks in Ψ: *Bubbles*

- The **bubble** concept is akin to the current layering model

- The basic building block of functionality at all levels
  - from OS
  - through LAN
  - to Global Internetwork

- Bubbles offer availability and extensibility through the **recursive** execution of basic functions
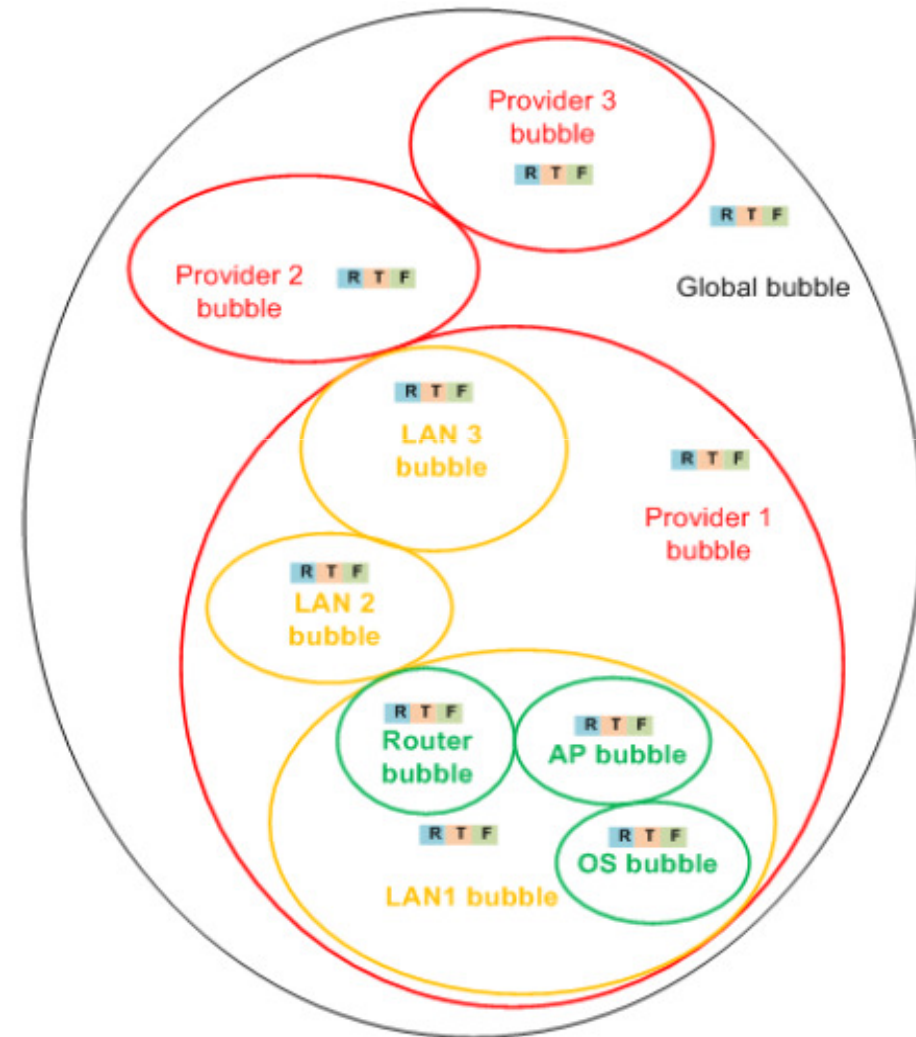
Mobility and Privacy support

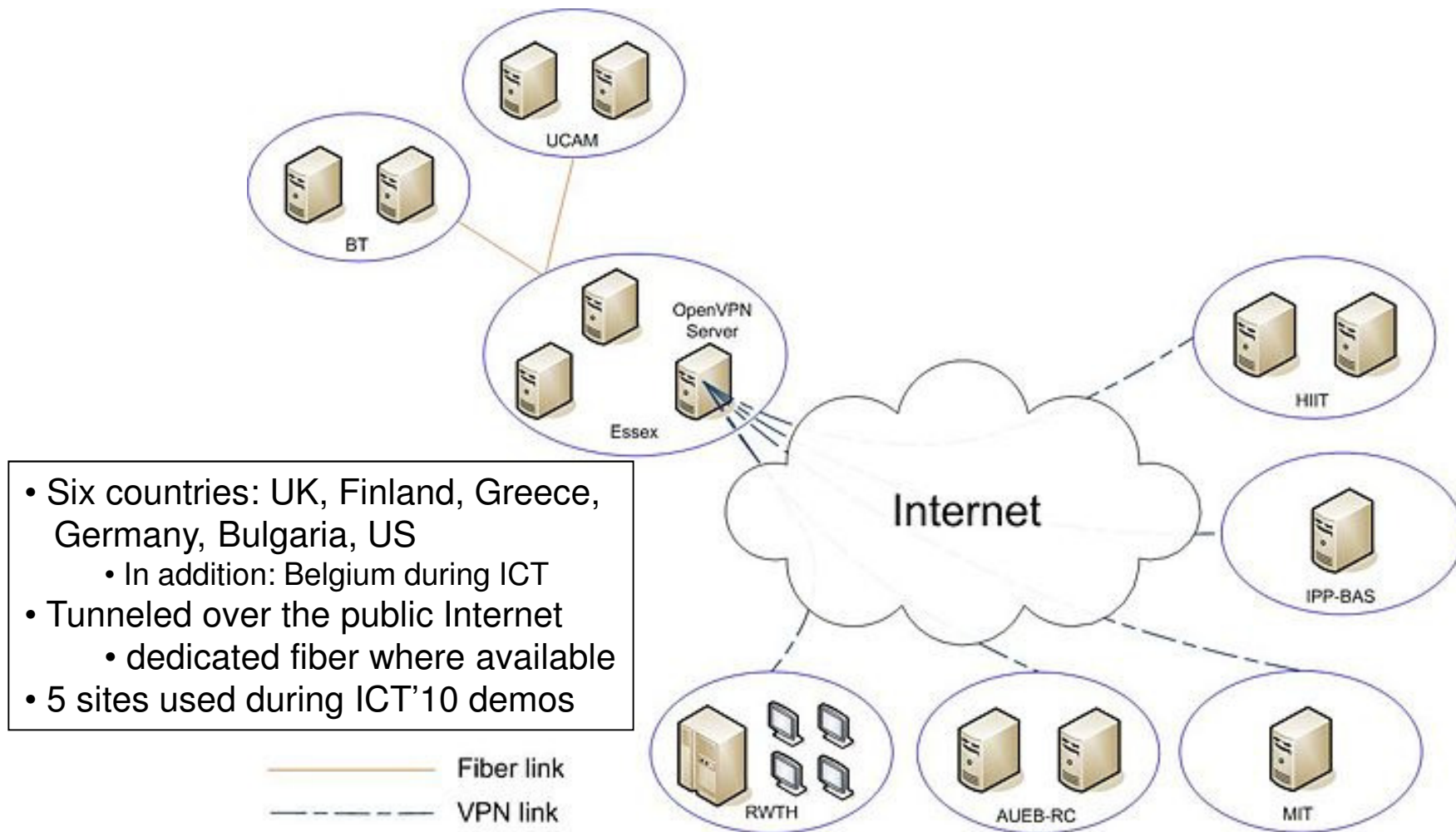- Bubbles support mobility as well as location privacy
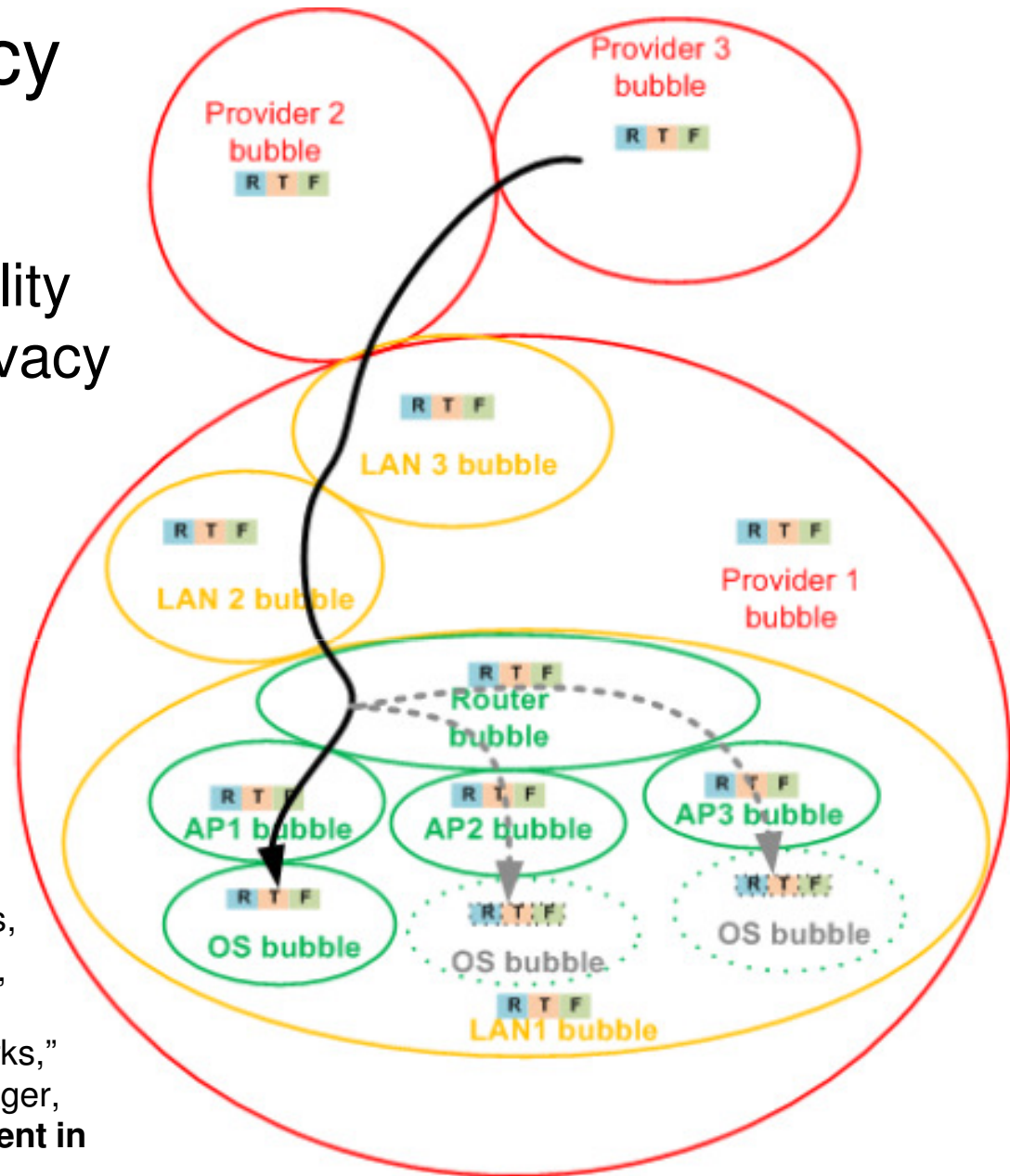
N. Fotiou, K.V. Katsaros G.C. Polyzos, M. Särelä, D. Trossen, G. Xylomenos, "Handling Mobility in Future Publish-Subscribe Information-Centric Networks," *Telecommunication Systems*, Springer, Special Issue on '**Mobility Management in the Future Internet**,' to appear.

Advantages of PSI in Mobility Support

- Publishers & Subscribers can seamlessly & simultaneously move
    - Data (packets) are identified independently from source or destination
    - Information (cached? content) is still transparently available
- Publish/Subscribe is **asynchronous** and **multicast**
    - Demand for content served without the need of the synchronous presence of a publisher (source)
    - Adapts better to frequent mobility
- Anonymity
    - subscribers and publishers remain anonymous (unlike IP)
- Routing and Forwarding
    - decoupling IDs from addressing is a major advantage
        - locations are ephemeral
        - no need for **triangular** routing
        - **ingress filtering** problem
        - **anycast** choice of the best source of content

# PSIRP Testbed

- Six countries: UK, Finland, Greece, Germany, Bulgaria, US
  - In addition: Belgium during ICT
- Tunneled over the public Internet
  - dedicated fiber where available
- 5 sites used during ICT'10 demos

Fiber link
VPN link

PURSUIT Testbed

- 25 nodes
- 5 countries:
  - UK
  - Finland
  - Greece
  - Germany
  - USA
- Tunneled (VPN)
  - over the public Internet

VM Topology (for blackadder or anything else running in Linux)
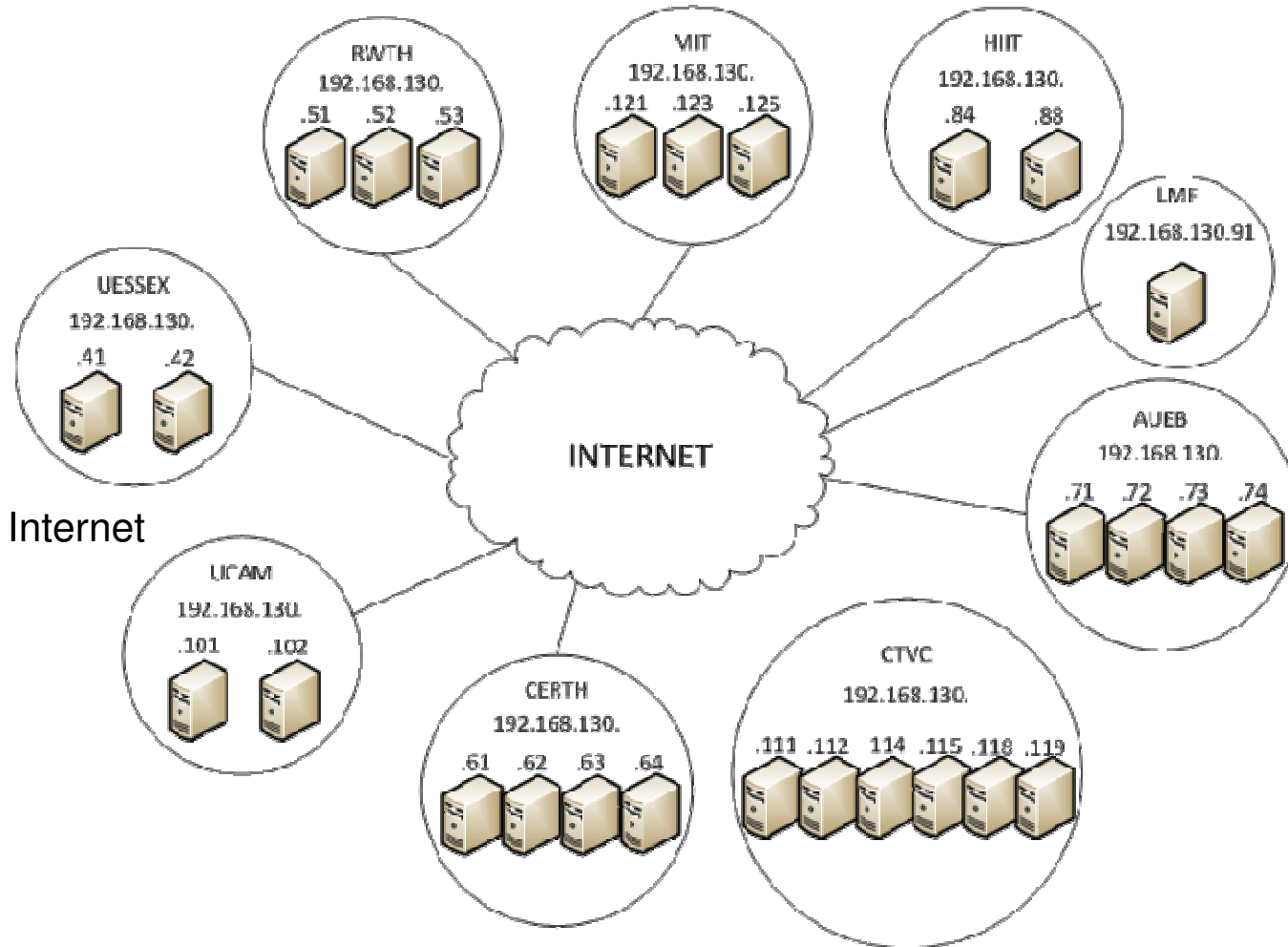
Components of a Ψ based Assistive Environment

- **Storage Devices**
- **Monitoring Equipment**
  - Small devices deployed close to the person and on his body
- **Patient Visualization Equipment**
- **Content Transformation Nodes**
  - Network nodes that are able to transcode content

- *Connected through a Ψ network*
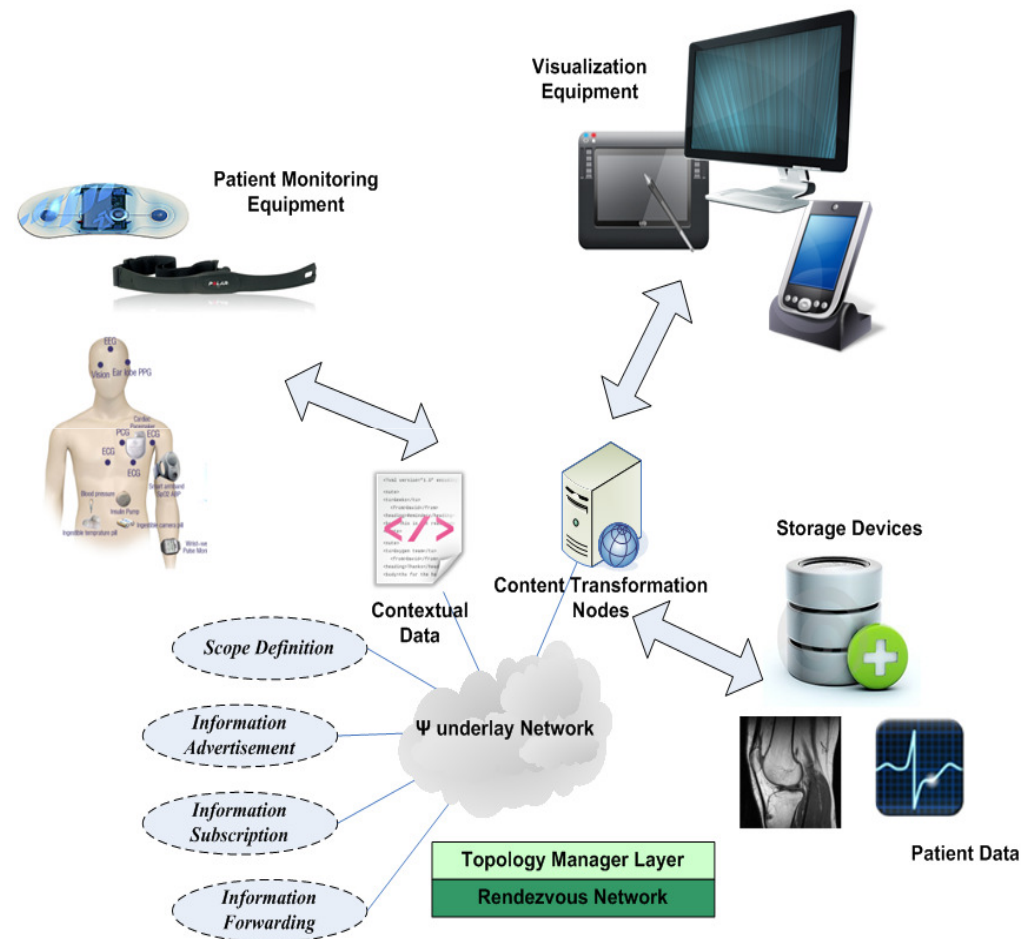
Use case of an Emergency Scenario

- **Scope Definition**
  - Create scope with the following policy: "if the health status of patient X is normal, only doctor Y can subscribe, in case of emergency the relatives of X as well as doctors that are located inside hospital M can subscribe"
- **Information Subscription**
  - Subscribe to scope "request for help"
- **Information Advertisement**
  - Advertise medical data as always
  - In case of emergency advertise to scope "request for help"
- **Information Forwarding**
  - Access control policies are relaxed and information is forwarded to the subscribers defined in the emergency access control list

Benefits

- ## Applications remain the same
  - Focus on their actual purpose: generate data

- ## Flexibility
  - Network is (re)programmable

- ## Interoperability
  - Subscription
  - Advertisement
- ## Security (Access)
  - Implemented by the network

Conclusions

- ICN is better positioned to address

  - mobility, caching, security...
  - evolution & tussles resolved at or near run-time

- The Ψ architecture inherits the advantages of ICN & the publish/subscribe paradigm

  - in particular the security ones, but….

- PSIRP & PURSUIT selected and added specific security mechanisms

  - Packet Level Authentication
  - Secure Forwarding (zFilters)
  - Scopes
  - Bubbles
  - Information ranking

- ICN/PSI is better positioned to address

  Context-Aware Information Delivery in Assistive Environments

Thank you!

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