Design Challenges of Open Spectrum Access

K.V. Katsaros, P.A. Frangoudis, G.C. Polyzos, MMlab, **AUEB**, GR
G. Karlsson, EE, **KTH**, SE

George C. Polyzos

Mobile Multimedia Laboratory

Department of Informatics/Computer Science
Athens University of Economics and Business
47A Evelpidon, 11362 Athens, Greece

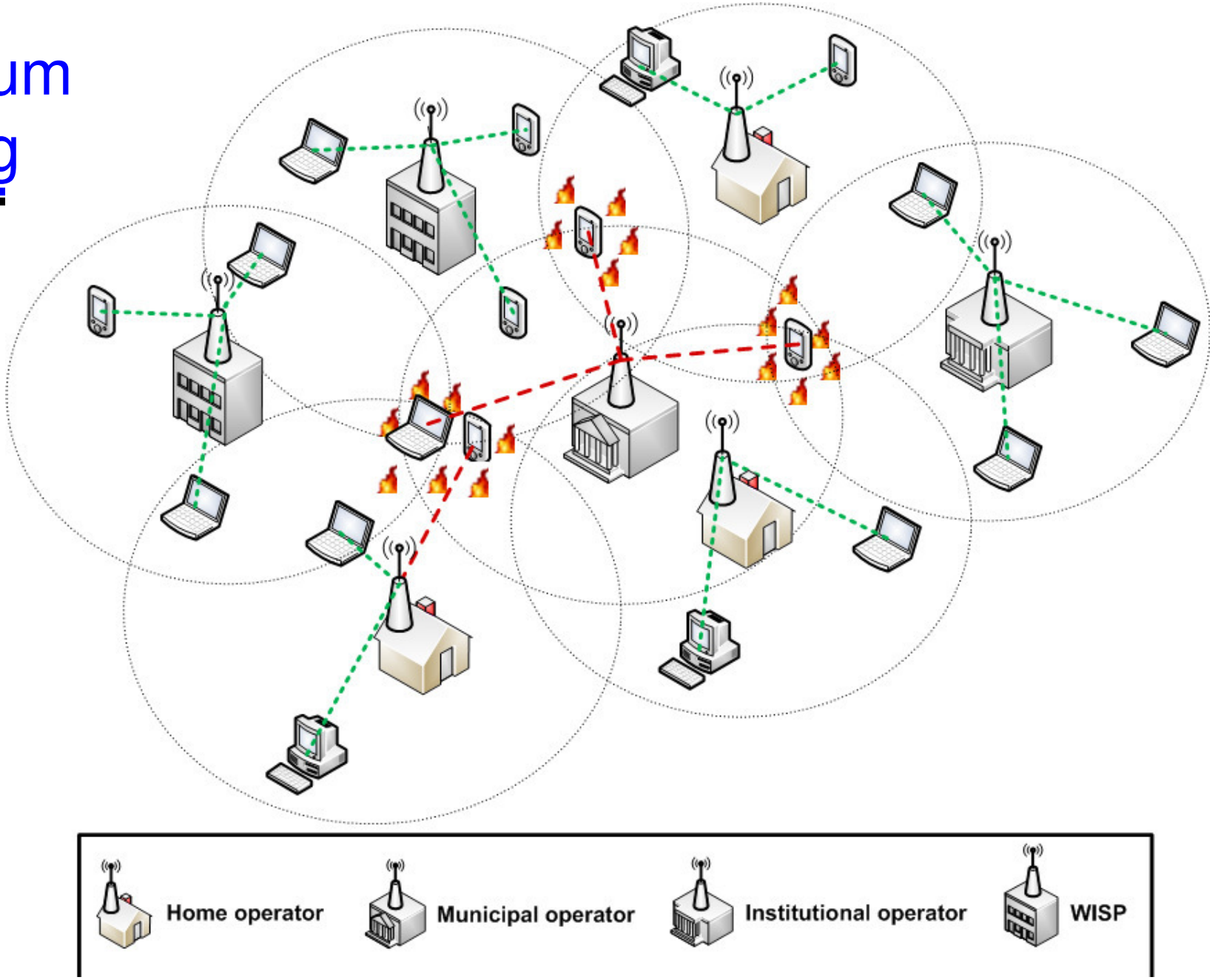
polyzos@aueb.gr, http://mm.aueb.gr/
Tel.: +30 210 8203 650, Fax: +30 210 8203 325

CRNETS 2008, Cannes, French Riviera, France, September 2008

The Problem

- Proliferation of wireless networks & devices
- Increased demand for radio spectrum
  - Need for regulation …
- Traditional approach rather inefficient
  - Difficult to find a vacant frequency
  - Competition leads to need for high investments
    - High entry barrier for new operators
    - Long payback time
    - Customers tied to a specific network
      - Often impossible to choose the best price-quality
  - Frequency bands tied to specific technologies
  - Licensed bands
    - temporal & spatial underutilization of the spectrum
  - Unlicensed bands
    - interference

Spectrum Sharing



The Role of Cognitive Radio

- Interact with the wireless environment
  - Sense, learn and adapt/react
- mostly focused on the Primary/Secondary user model
  - Focus on spectrum underutilization
    - Filling spectrum *holes*
  - Spectrum access priorities
- However…
  - still hard/risky for secondary users/operators
    - primary user priority hinders even the minimum service guarantees
  - primary operator investments still key for growth of wireless networks & services

Key Survey Papers

- Qing Zhao and B.M. Sadler, "**A Survey of Dynamic Spectrum Access**," ***IEEE Signal Processing Magazine***, vol. 24, no. 3, pp. 79-89, May 2007.

- I. F. Akyildiz, W.-Y. Lee, M. C. Vuran, and S. Mohanty, "**Next Generation/Dynamic Spectrum Access/Cognitive Radio Wireless Networks: A Survey**," ***Computer Networks***, vol. 50, no. 13, pp. 2127-2159, September 2006.

- S. Haykin, "**Cognitive Radio: Brain-Empowered Wireless Communications**," ***IEEE Journal on Selected Areas in Communications***, vol. 23, no. 2, pp. 201-220, Feb. 2005.

Alternative Spectrum Utilization Model

- Unlicensed spectrum
  - Anyone can become an operator
    - Residential WLAN owners, (W)ISPs, municipalities, etc.
    - No inter-operator or inter-technology priorities in principle!
  - Increased competition
    - Better service offerings
      - Subject to operator/user interactions and not preset priorities
    - Increased interference
  - Low entry cost
    - Increased coverage
- Open access
  - Without any form of prior contract (subscription)
  - Getting (buying?, exchanging?) network access in small quanta

The Proposed Architecture

- Utilization of client-supplied information
  - Outer feedback loop
  - Spectrum usage, service offerings
  - Hidden interference problem …
  - Planning AP deployment
  - Cheap sensors deployed to supply spectrum utilization information
- Adaptive wireless infrastructure
  - Inner feedback loop
  - Interference mitigation
- Service discovery, negotiation and handovers
  - *Direct:* mobile node – AP interactions
  - *Indirect:* user reports

The Proposed Architecture:
Functional Requirements

Mobile Node

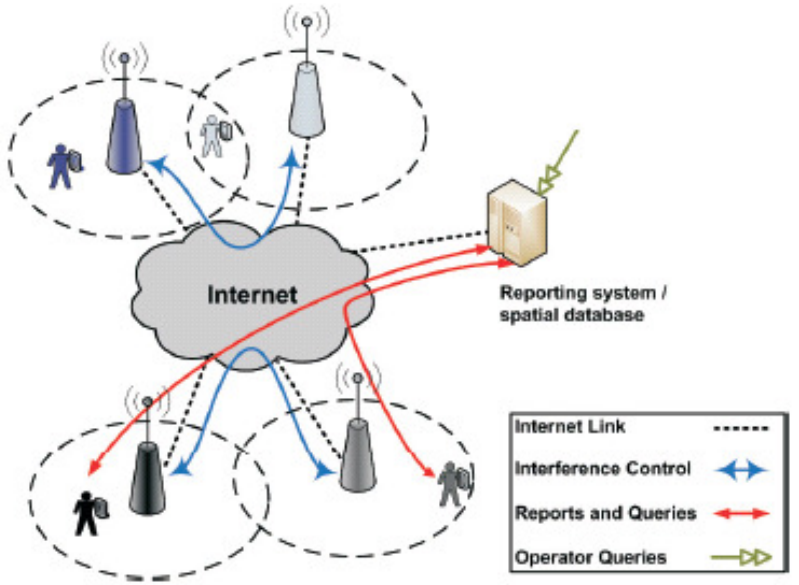
- Spectrum sensing
- Service discovery
- Reporting (especially of *white spots*)
- Spectrum agility
- Secure micro-payments
- Advanced handover capabilities (frequency, air interface, AP, operator)

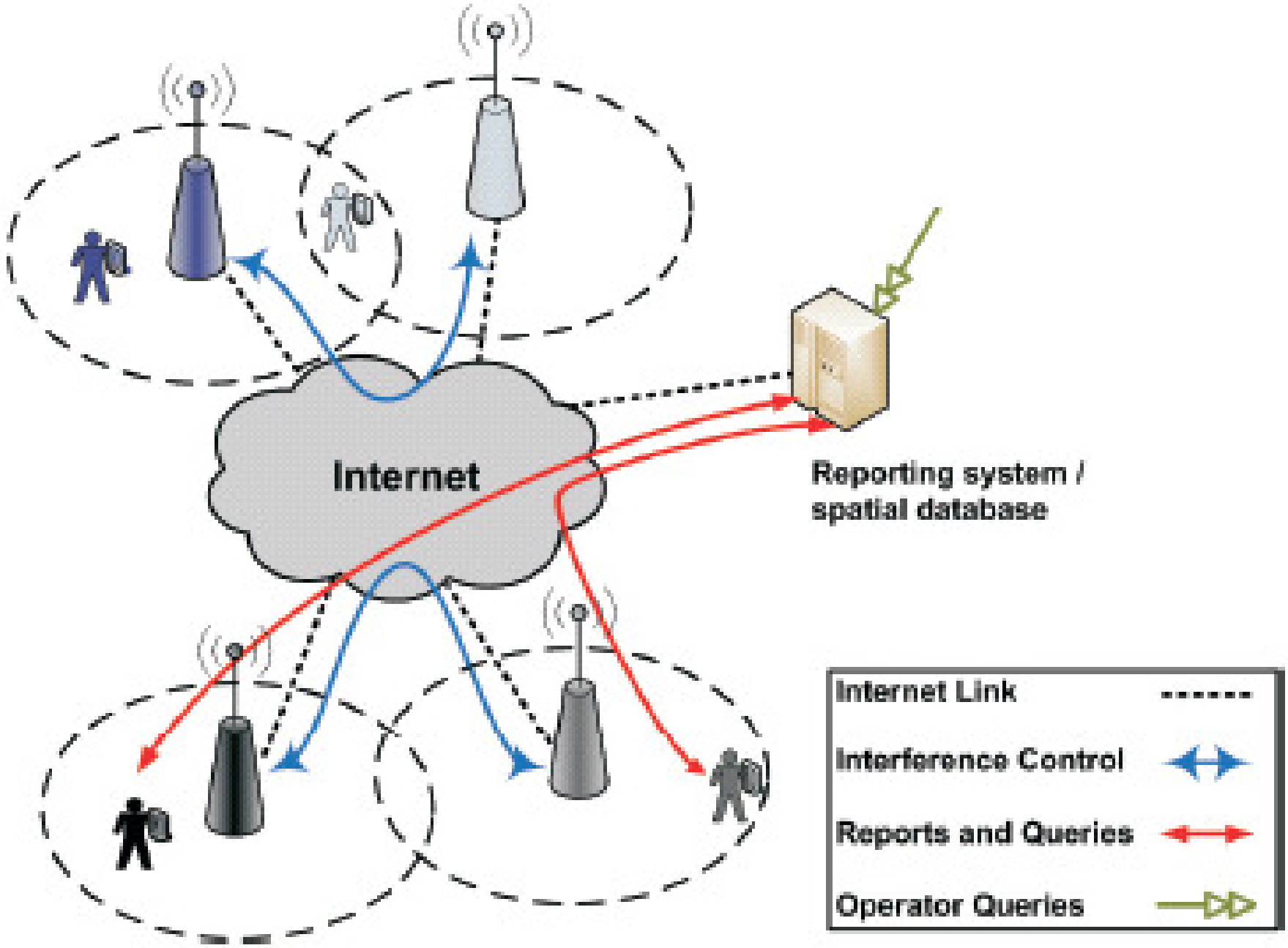
Reporting System/Spatial Database

- Aggregate reports
- Monitoring
- Provides information on service availability and spectrum usage
  - Operators: *white* spots, interference, etc.
  - Users: coverage, services, etc.

Access Point

- *Announcing*
  - *Spectrum portfolio*
  - *Service capabilities*
- Secure micro-payments
- Interference feedback and reporting
- Interference control
- Handover preparation




Internet
Reporting system /
spatial database
Internet Link
Interference Control
Reports and Queries
Operator Queries

Dynamic Spectrum Access:
Challenges and Goals

- *Spectrum sharing dimensions:* frequency, space and time
  - A unified framework considering all dimensions will provide the necessary flexibility (unlicensed spectrum)
- *Primary/Secondary model vs. Open Spectrum Access (OSA)*
  - OSA enables new (micro-)operators to enter the market
- *Centralized vs. distributed*
  - Outer/inner feedback loop
  - Goal: a low overhead reporting system
- *Cooperative vs. non-cooperative spectrum sharing*
  - Design incentives that will lead to a high degree of cooperation between competing spectrum users
- *Game theoretic modeling of spectrum sharing*
  - Various degrees of cooperation
    - Expressed by the amount and quality of the available information
  - Translation of a game-theoretic model to a practical system

Our Related Work

- **"Stimulating Participation in Wireless Community Networks"**
  - E.C. Efstathiou, P.A. Frangoudis, and G.C. Polyzos
  - Proc. IEEE INFOCOM 2006, Barcelona, Spain, April 2006
- **"Power Control in WLANs for Optimization of Social Fairness"**
  - V. Douros, K. Katsaros, P.A. Frangoudis, and G.C. Polyzos,
  - Proc. 12th Pan-Hellenic Conference on Informatics (PCI'08), Samos, Greece, August 2008
- **"Optimizing the Channel Load Reporting Process in IEEE 802.11k-enabled WLANs"**
  - E. Panaousis, C.N. Ververidis, and G.C. Polyzos
  - Proc. IEEE LANMAN 2008, Cluj-Napoca, Romania, September 2008
- **"Coupling QoS Provision with Interference Reporting in WLAN Sharing Communities"**
  - P.A. Frangoudis and G.C. Polyzos,
  - Proc. Social and Mesh Networking Workshop (IEEE PIMRC 2008), Cannes, France, September 2008

Additional Related Work

- **Gunnar Karlsson's work on WLANs**
  - support for mobility, handover
  - very large WLANs (WMANs) / distribution network

- The ASPECTS project: Agile SPECTrum Security
  - Euro-NF NoE Specific Joint Research Project
    - AUEB
    - Blekinge Institute of Technology (M. Fiedler),
    - Universität Passau (H. de Meer)

Conclusions

- New wireless networking paradigm
- Organic growth of wireless networks
  - micro-operators
  - micro-payments
  - getting service in small quanta
- Focus on unlicensed spectrum
  - foster inter-operator competition
    - and cooperation (information exchange…)
  - increase coverage
    - increase available bandwidth to users
  - lower cost to users / society

Thanks!

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