Mobility in Wireless Networks

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http://netlab.cs.ucla.edu/mwnet/usemod10/wiki.cgi?Main

The Mobile Internet

- New generation of powerful portable devices:
  - Can support most Internet needs
- Wireless speeds growing constantly:
  - 4G expected to achieve 40Mbps
  - WiFi up to 100Mbps
- Opportunistic ad hoc networking facilitates P2P applications

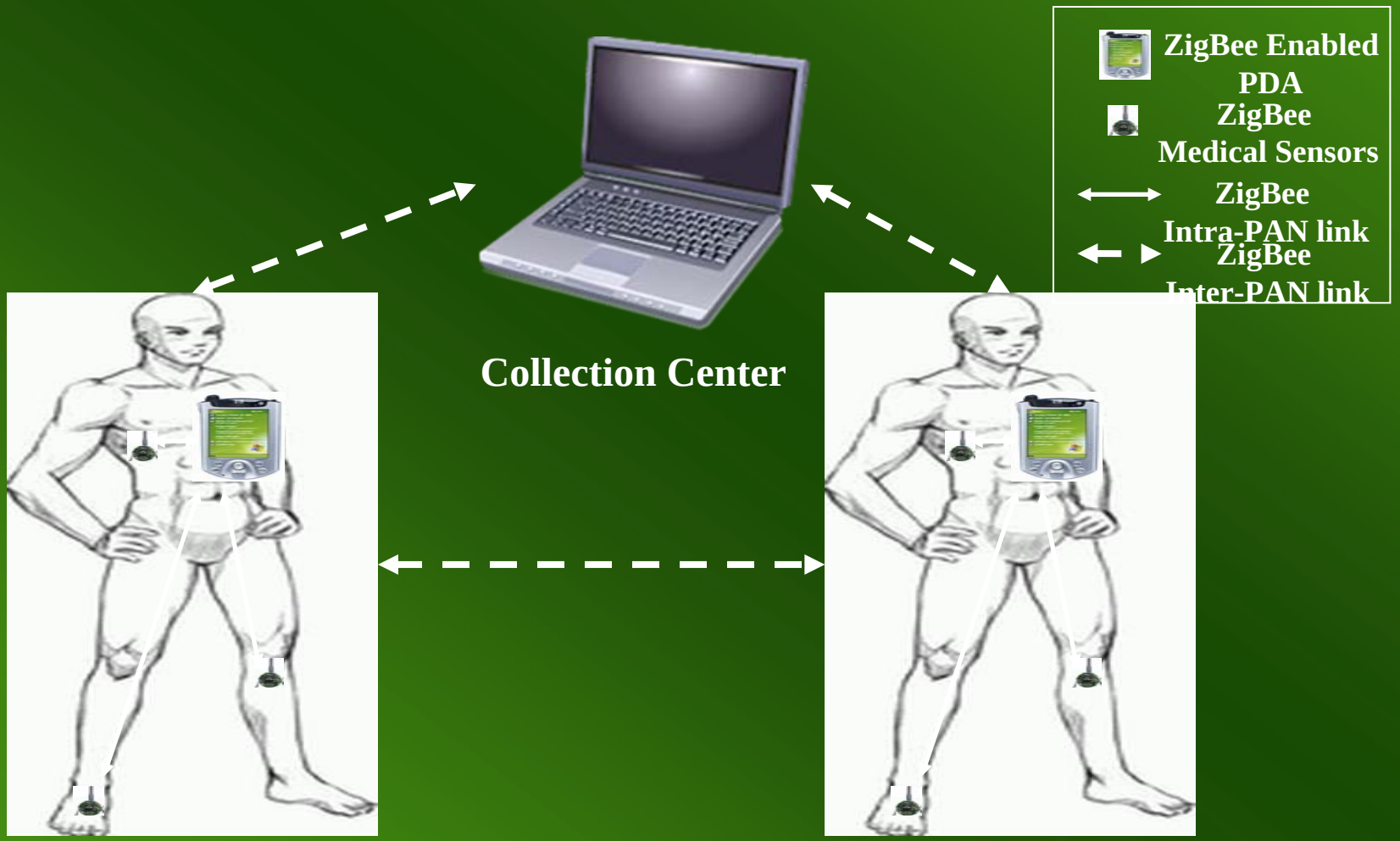
The paradigm shift

- Traditional wireless mobility:
  - Last hop connectivity
  - Soft handoff (horizontal, vertical)
  - Most data and services still in the wired Internet
  - Advanced ad hoc networking only in *tactical and emergency scenarios*

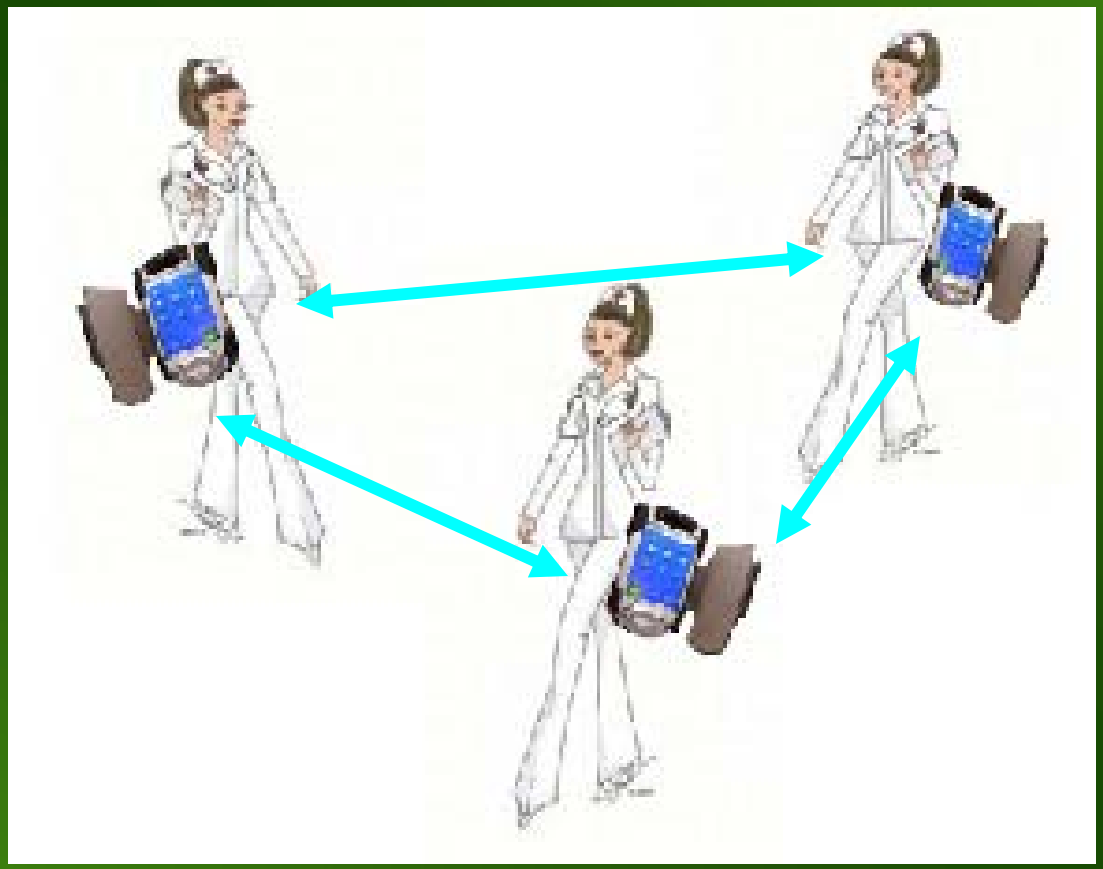
The paradigm shift (cont)

- Emerging Wireless, Mobile Internet
  - The data is collected by portable devices, and may stay (and be searched) on the devices for a long time:
    - Urban sensing (vehicle, people)
    - Medical monitoring, etc
  - This creates new challenges
    - Distributed index (ie, publish/subscribe) to find the data
    - Data sharing among mobilers via opportunistic P2P networking
      - Infrastructure used if more efficient than pure wireless: *"Reconfiguring the Infrastructure"*
    - Privacy, security, protection from attacks
    - Intermittent operations (mobile nodes can become disconnected); delay tolerant applications; disruption tolerant networks

Collaborative Health Monitoring: ZigBee as Health-Net



Nurses Cache-and-Forward Patient Data to Doctors



Objectives of the NSF Workshop

- How does “mobility” change traditional network architecture and design?
  - Applications
  - Protocols
  - Mobility models
- What new research is needed to make progress?

Emerging Mobile Applications

A New Generation of Mobile Applications

- Distributed
- Integrating heterogeneous infrastructure (e.g., WiFi, cellular, satellite) and ad-hoc networking
- Location-aware
  - Opportunistic, predict, control
- Exploit mobility
  - Homogenous or heterogeneous mobility
  - Individual or swarm mobility
- User behavior-aware
- Location privacy sensitive
- Self-configurable, self-tunable, remotely manageable
- Energy-aware

Mobile Application Examples

- Vehicular applications
  - Safety, traffic information, route planning
- Content-sharing applications
  - Entertainment (video, audio), games
- Mobile external sensing
  - Urban pollution sensing, accident reporting
- Mobile ad-hoc services
  - Relaying to near-field users
- Emergency applications
  - Disaster recovery
- *Mobile network management*
- *Mobile social networking*
  - *Mobile Facebook*

Research Challenges

- Mobile application design
  - Location-aware, exploit mobility, gathering feedback and traces
- Performance and QoS
  - Delay tolerance, channel variations
- Cross-layer communication design
  - Exploit mobile application context information
- Security issues
  - Location validation, Location privacy, Trust management
- Social aspects
  - Event-driven and event-generated mobility

Robust, Motion Resistant Protocols

Main Message

- Changing the view on mobility:
  - Mobility has become an integral attribute of the Internet and we need to design for it.
  - Without mobility support, the Internet cannot be invisible.
- There is a big gap between the opportunities that mobility enables and the practical protocols that can take advantage of it.
- Design for mobility requires a clean-slate approach to communication protocols in wireless networks and the Internet
- Design for mobility has direct implications on the Internet design, in-network storage and localization information being key factors
- Standards are needed for benchmarks.

Why Is Mobility Important? (1)

- Mobility impacts:
  - the conditions in which protocols must operate,
  - the state and context that nodes can use to communicate, and
  - the problems that protocols must solve.
- Examples:
  - *The state of links is a function of mobility* (e.g., link lifetime, fading, multipath effects, direction of a link, etc.)
  - *The neighborhood of a node changes with mobility*, which impacts reliable exchanges, channel division (space, time, code, frequency) among neighbors, and forms of cooperation between senders and receivers (e.g., virtual MIMO, network coding)
  - *End-to-end paths change with mobility*, which impacts path characteristics (in-order delivery, delay, throughput, lifetime of paths, etc.) and the allocation of resources over paths to satisfy application requirements.

Designing for Mobility

- Some protocols benefit from mobility: group mobility, etc.
  - Use mobility as a mechanism for information dissemination
- Controlled mobility:
  - nodes move around to improve topology, deliver data, store-carry-forward,
  - trajectory planning and changing what routes
- Interest-driven “physical” dissemination:
  - How should opportunistic data mules handle data?
- Content-driven routing

Mobility Models and Mobile Testbeds

Model Flexibility

- Multiple scale models
  - Micro and Macro levels, (e.g., from stop signs to cross town patterns
- Multi-faceted scenarios
  - Combines motion, data traffic, map, infrastructure
  - Interrelation between data/motion; data caching; aggregation, etc
- Trade off between accuracy and usability
  - Different applications may focus on different parameters

Traces to Models

- Traces:
  - Lack of cellular traces (owned by providers)
  - Lack of vehicular traces (not enough testbeds)
  - Lack of social network tracing experiments
  - Scarcity of urban traces
- Interplay/synergy of:
  - Measured traces
  - Synthetic models/traces
  - Theoretical motion/traffic models

Metrics and Parameters

- Motion Impact on Data Performance:
  - How are the metrics impacted by the particular motion patterns,
  - How do the motion patterns impact the traffic,
- Consider new “mobility” measures:
  - Inter-contact time, neighborhood change rate, partitioning, clustering, etc
  - Ideally, a few ***motion “primitives”*** that can cover most scenarios and allow cross comparison of test experiments

Performance Benchmarks

- Well defined benchmarks
- Knobs, ie, flexibility
  - Need to understand effect of knobs
  - Need knobs tunable to applications
- Sound design methodology
  - Ability to tradeoff accuracy, complexity etc
  - Verifiability

Testbeds

Testbed Flexibility

- Multi-layer multi-user vs. single layer/user testbeds
- Heterogeneous (hardware, protocols, applications)
- Broad range of motion patterns:
  - From pre-scheduled to controlled and spontaneous
- Broad Range of devices:
  - From small scale testbeds (motes) to large scale testbeds (vehicles)

Testbed Scalability

- Testbed expansion with simulation and emulation
- Integration with real world networks and applications

Testbed Realism

- Need more than what simulation already gives us!!
- Need to understand:
  - Realistic user behavior in reaction to motion, data etc
  - Realistic channel behavior
  - Real implementation/HW constraints
- Uncover:
  - interactions between layers and inefficiencies
  - Incorrect common beliefs
- Appreciate:
  - HW, SW, Mgmt costs

How can the Internet (and GENI) support mobile applications?

- Addressing and routing
  - Geo-routing
  - More generally, attribute based routing
  - Mobility support
- Interaction with the infrastructure
  - Off loading the wireless internet
- Wireless as emergency network
  - When the infrastructure is brought down
- Congestion control assistance
- Security, protection against attacks