Nomadic Wireless Sensor Network for Autonomic Pervasive Environments

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Presentation Outline

- Motivation
  - Future Autonomic Pervasive Environments
- Nomadic Wireless Sensor Network
  - Architecture and Protocols
- Case study: a parking lot finding application
  - Simulation description
  - Simulation results
- Conclusions and future work

Future Pervasive Environments

- Multitude of “interconnected smart devices”
  - Every object equipped with a radio transceiver
- Extremely heterogeneous devices
  - Sensors, RFIDs **vs.** PDAs, laptops, smart phones
  - Different logical roles in the network
    - Source of information vs. consumers of information
- Extremely dynamic environment
  - Opportunistic autonomic communications
- Moving away from data transmission systems
  - Information mostly related to a specific context
    - Exchange *information* rather than *data*
  - Situated communications and services

Different Solutions for New Challenges

- Number of communicating devices is going to explode
  - the classical end-to-end approach is not a viable solution
    - Difficult to address every single node
    - Not possible to manage such a network
- The quantity of data flowing in the network is going to explode
  - Traditional communication can hardly deal with all this

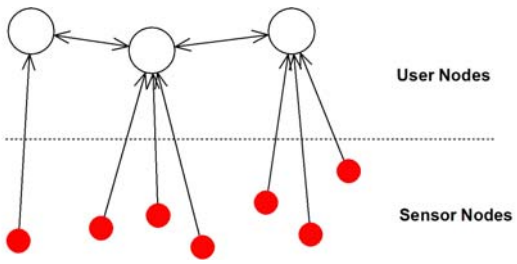
Call for new communication paradigms!

Nomadic Sensor Network Architecture (NSWN)

- 2-Tier network architecture
  - ***Sensor Nodes (S-Nodes)***
    - Extremely simple and cheap
    - Provide information about
      - An object (RFIDs)
      - Or the environment (sensors), …
    - Augmenting pervasive services
  - ***User nodes (U-Nodes)***
    - Sophisticated mobile devices
      - Powerful in terms of available energy, processing power, communication and storage
    - "Physically" moving together with the user
    - Running pervasive services

Nomadic Sensor Network Protocols

- **S-node**:
  - Only read by U-nodes in proximity
  - No store and forward policies
  - Single-hop broadcast communication
- **U-node**:
  - Store S-Nodes readings in their device memory
  - Diffuse stored information according to an epidemic-like relaying algorithm while moving
    - Exploitation of the users' mobility
    - No need for routing



Information Filtering

- *Information Filtering* mechanism to manage the exchanged data
  - Applied by U-nodes' services on the exchanged information
  - Exploit the spatial/temporal dependence of the exchanged data for removing useless information
    - No need to diffuse information outside the region of utilization/interest
  - Reduces networking requirements
    - Shifting the complexity at the service level

Case Study: Parking lot Finding System

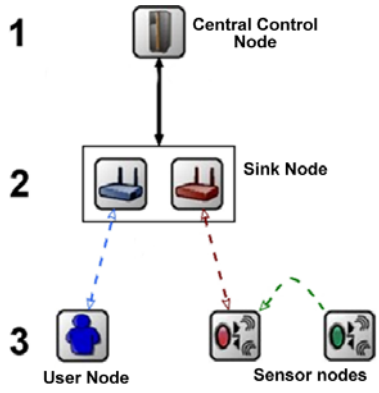
- Parking lot finding application
  - Each parking spot of the city is equipped with a sensor
  - City is uniformly subdivided into *blocks*
    - Area around the train station, around the Theater,..
  - Mobile users are looking for a free parking spot in a random block
  - Parking lot finding system is guiding the user to a free parking spot
    - Suggests the nearest free parking spot in the chosen block
- Evaluated through simulations
- Nomadic Approach vs. Centralized System vs. Random Search

Random Search Model

- Random search model
  - No system assistance in the search of a free parking spot
    - Users drive randomly
    - Choose a random block
    - Once entering it, moves randomly as long a free parking spot is not found

Centralized Model

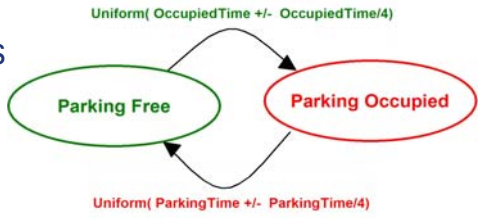
- Hierarchical network architecture
  - *WSN* for gathering data from sensors
    - AODV routing
    - Proactively updating Central Control Node
  - *Sink* communicating with sensors, users and central node
    - Wired communication with central control node (CCN)
    - 802.11 communication with mobile users
  - U-Nodes querying the central node through the sink
  - Central Control Node running the service
    - CCN updating the destination
    - CCN virtually reserving a free parking spot



Simulated Users

2 kind of simulated users:

- ***Served users***
  - Running the parking lot finding service
- ***Unserved users***
  - transparently freeing and occupying the parking spots
    - *OccupiedTime* is the time the parking is occupied
    - *FreeTime* is the time the parking is left free
      - The lower is the FreeTime the more difficult is to find a free parking spot
  - Implemented in the sensor



Unserved users behavior

Served Users Simulated Behavior

- Users behaves cyclically according to the following three steps:
  - **Driving**
    - users move randomly for a random *DrivingTime.*
  - **Searching**
    1. user selects a random block as the destination
       - Corresponds to “Look for a parking near the station”
    2. queries the parking lot finding system
       - Application provides the coordinates of a sensor expected to be free
    3. moves to the destination
    4. if the destination is free parks, otherwise goes back to 2
  - **Parking**
    - user parks for a random *ParkingTime*

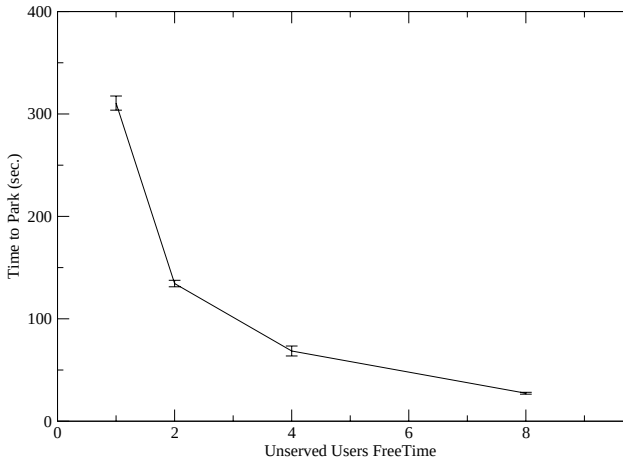
Performance Metric

- *Time to Park* : time needed for a user to find a free parking spot starting from the instant he enters the destination block
    - Metric independent from the initial position of the user

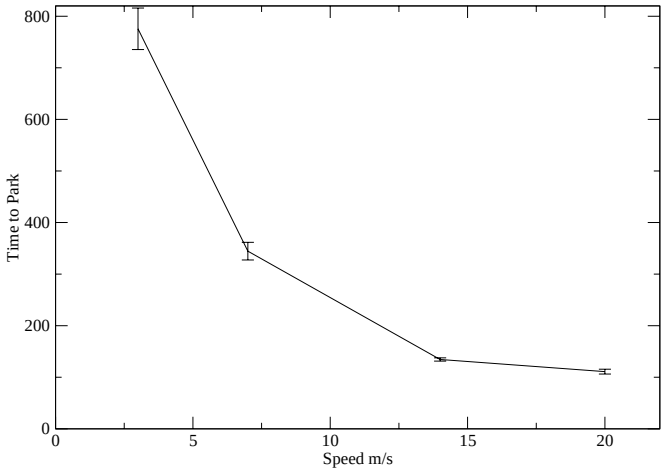
Simulation Settings

- Square area of 4000 x 4000 m
  - City uniformly subdivided into 16 blocks
  - 2028 sensors uniformly distributed, 50 m distance among 2 of them
  - Served users
    - moving according to a Random Waypoint mobility pattern over a manhattan network
      - 13 x 13 streets, 2 lanes each
    - 802.11 protocol, 150 m communication range
    - Varied the number of mobile users
  - Unserved users
    - variable FreeTime (2 to 10 minutes), 80 minutes OccupiedTime
- Each simulation is evaluated with its 95% confidence interval
- Scenario simulated in Omnet++

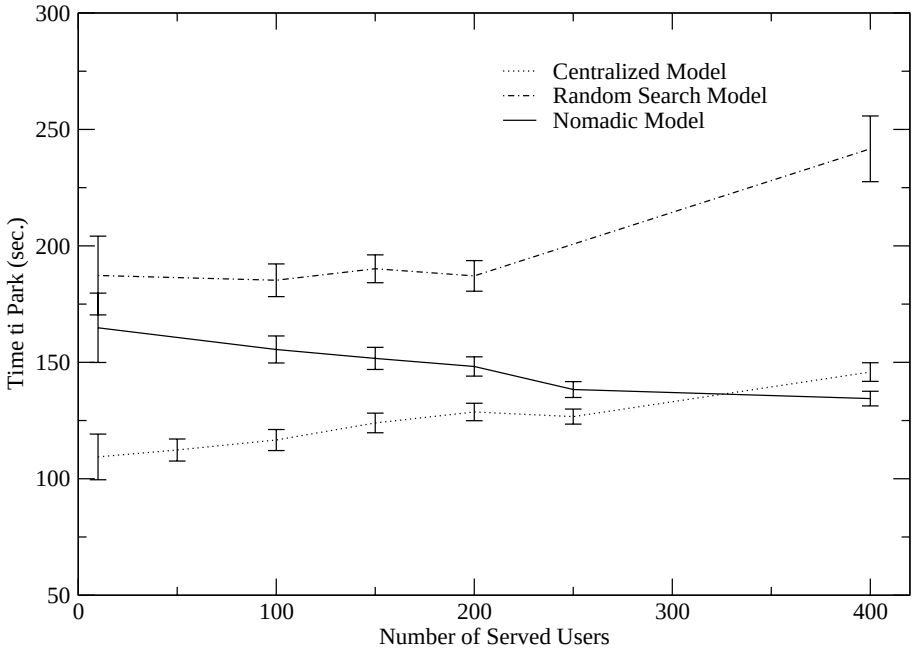
Simulation Results



Time to Park in the case of the NWSN model with 400 served users and a variable number of unserved users' FreeTime



Time to Park in the case of the NWSN model with 400 served users and a variable speed



Time to Park in the considered models with 400 served users moving at a speed of 14 m/s and 2 minutes FreeTime of the unserved users

Conclusions and Future Research Directions

- Conclusions
  - NWSN architecture
    - enable an efficient spreading of information by means of opportunistic message exchanges
      - An adequate mobility of users is needed
    - Support of pervasive services
      - performance comparable to centralized solutions
- Future research directions
  - Define an analytical framework
    - of the epidemic-like spreading
    - of the information filtering mechanism
  - Define a general framework for services description
    - Evolution/adaptation