ITU Kaleidoscope 2011
The fully networked human?
Innovations for future networks and services

Effective Collaborative Monitoring in Smart Cities: Converging MANET and WSN for Fast Data Collection

Paolo Bellavista, Giuseppe Cardone, Antonio Corradi, Luca Foschini

University of Bologna

giuseppe.cardone@unibo.it

Cape Town, South Africa
12–14 December 2011

Presentation outline

- Wireless Sensor Networks (WSNs)
- Mobile Ad-hoc NETworks (MANETs)
- Integration of WSN and MANET
- WSN Hybrid rOuting prOtocol (WHOO)
  - Goal and design guidelines
  - Scenario overview
  - Software architecture
  - MANET formation
- Experimental evaluation
- State of standardization
- Conclusion and ongoing research efforts

Wireless Sensor Networks (WSNs)

WSN: network of autonomous devices that cooperate to monitor environment conditions

Features:

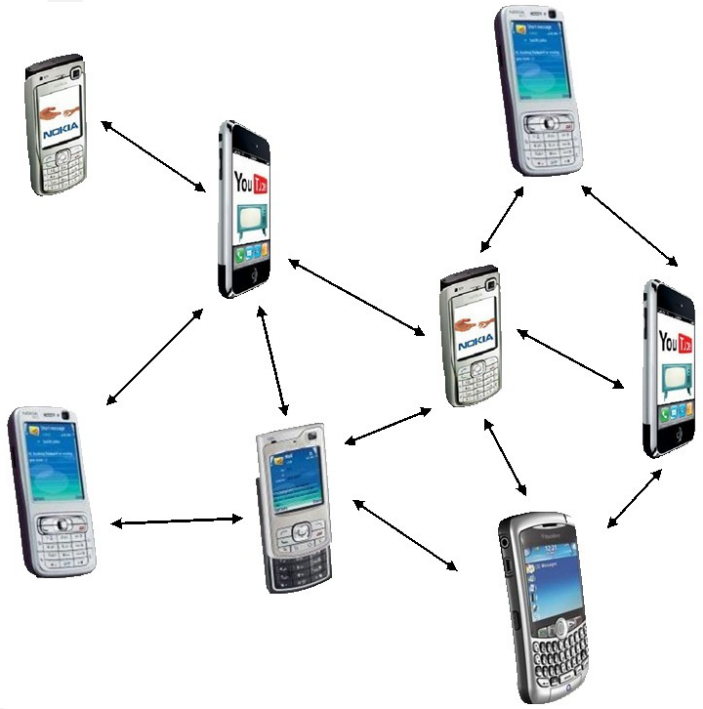
- self-organizing network
- data processing/aggregati
- low cost
- fast deployment

Mobile Ad-hoc NETworks (MANETs)

MANET: impromptu wireless network among heterogeneous mobile devices

Features:

- no infrastructure
- decentralized
- fast formation



Integration of WSN and MANET

Mobile phones can opportunistically exploit impromptu formed **MANET**s, to boost WSN performance:

- more computation power
- less energy constraints
- higher-speed and lower-latency network access

Mobile phones and devices have started to host onboard also novel low-power communications technologies, such as IEEE 802.15.4, so to enable technology for Internet of Things (IoT), Machine-to-Machine communication (M2M)

WSN Hybrid rOuting prOtocol (WHOO)

The motivating goal is to **monitor quality of life** indicators in Smart Cities:

- structural integrity of buildings
- pollution
- traffic

Goal:

- Opportunistically exploit MANET-WSN links to provide a backbone to route **urgent data** packets generated by the WSN

Advantages:

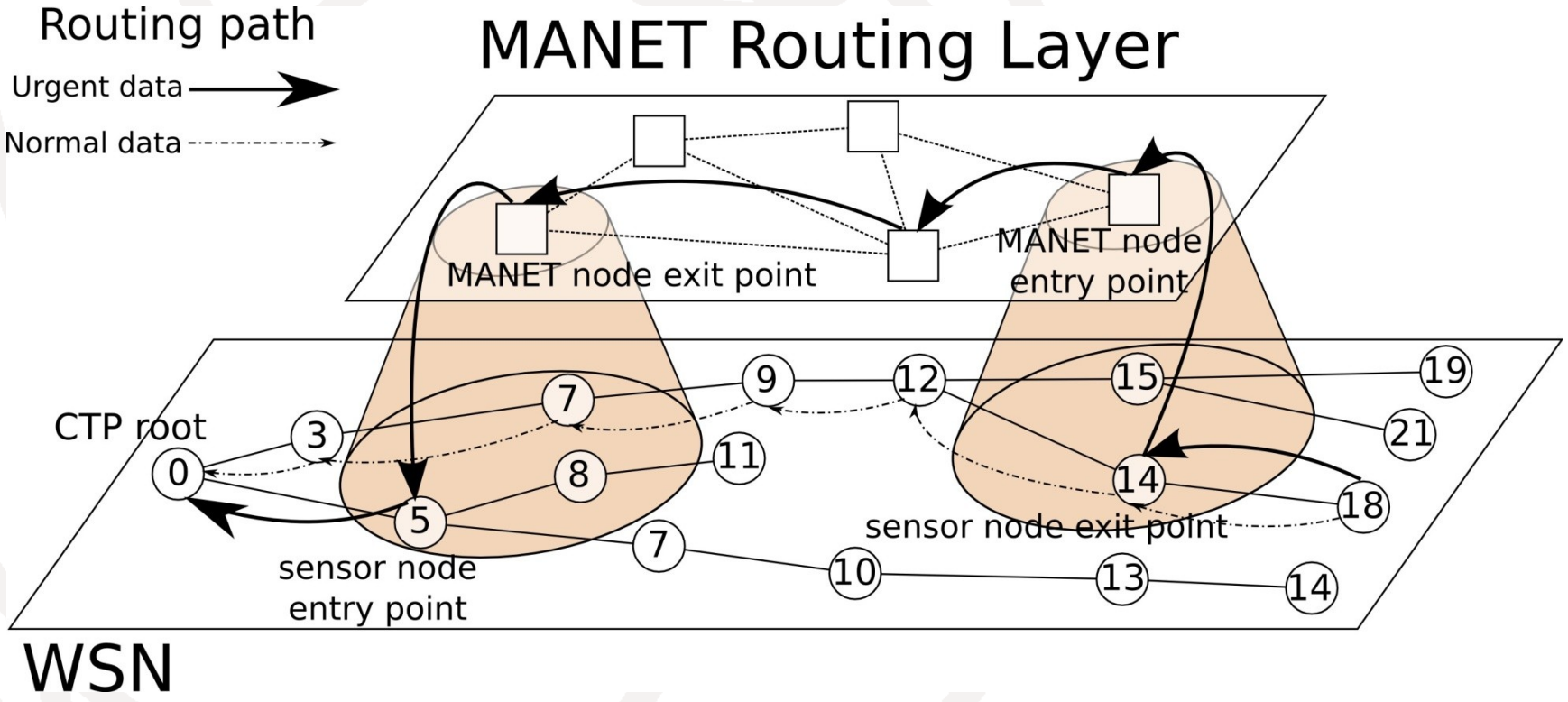
- **faster delivery** for urgent data
- **longer battery life** for sensor nodes

WHOO goal and design guidelines

- Design **guidelines**:
  - Energy-conservative
  - Opportunistic
  - Adaptive
  - Localized
  - Compatible with off-the-shelf technologies
- Desirable **requirements**:
  - Robust
  - Tolerant to disrupted low-power links
  - Completely distributed
  - Zero overhead when not used
  - Guaranteed and predictable overhead

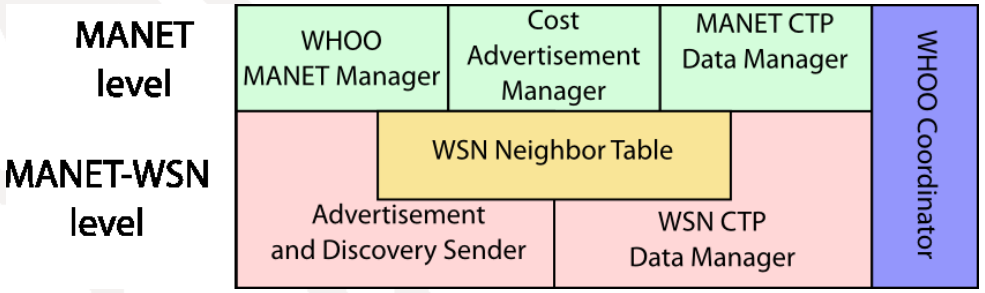
WHOO scenario overview

- Data collection on tree topologies
- Urgent and non-urgent packet pushed following a descending gradient to a root
- Mobile devices opportunistically self-organize in MANETs as backbone for urgent packets

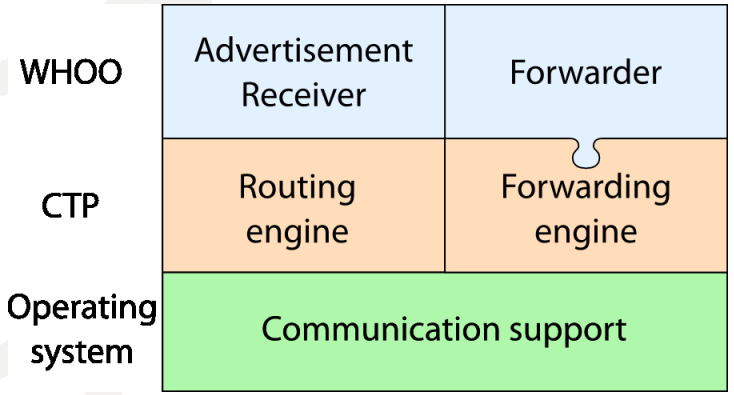


WHOO Software Architecture

MANET node software stack



Sensor node software stack

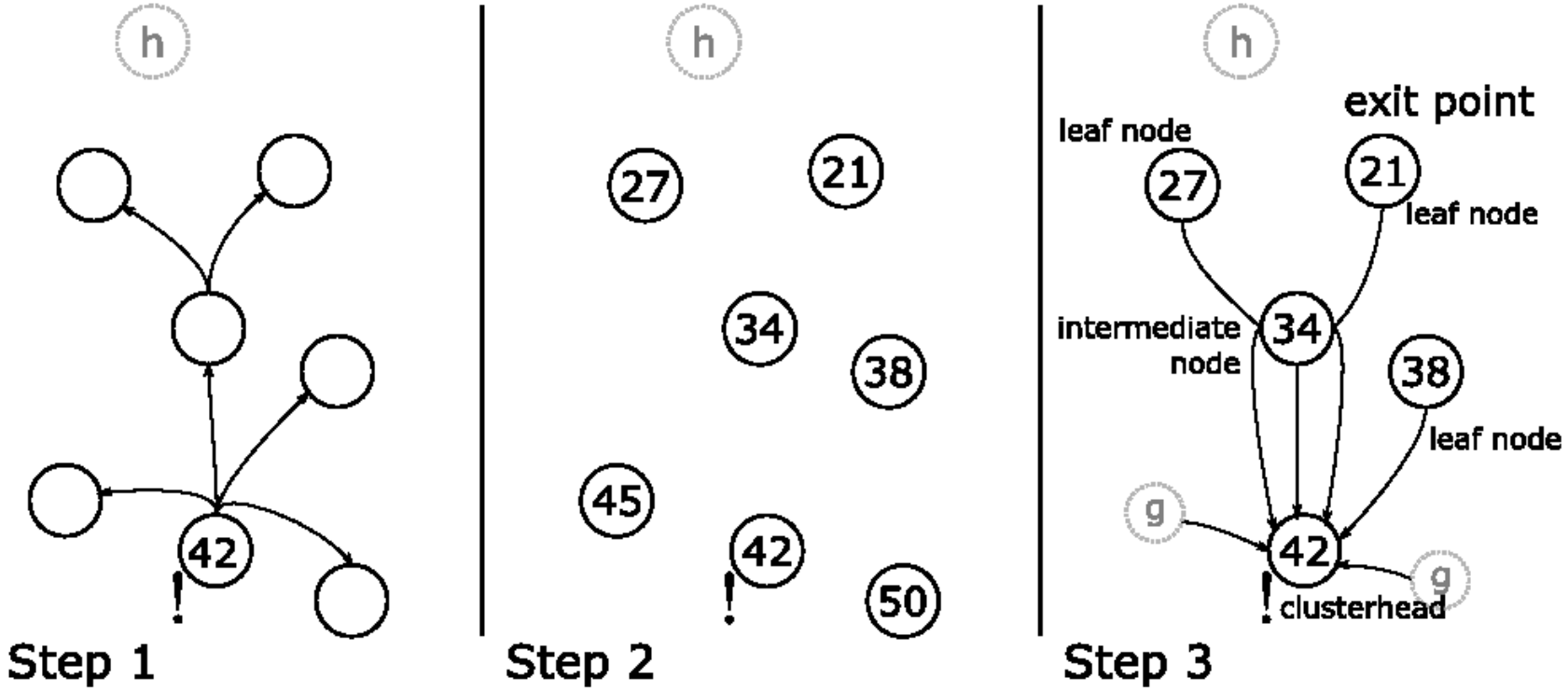


MANET formation

MANET node excluded with motivation

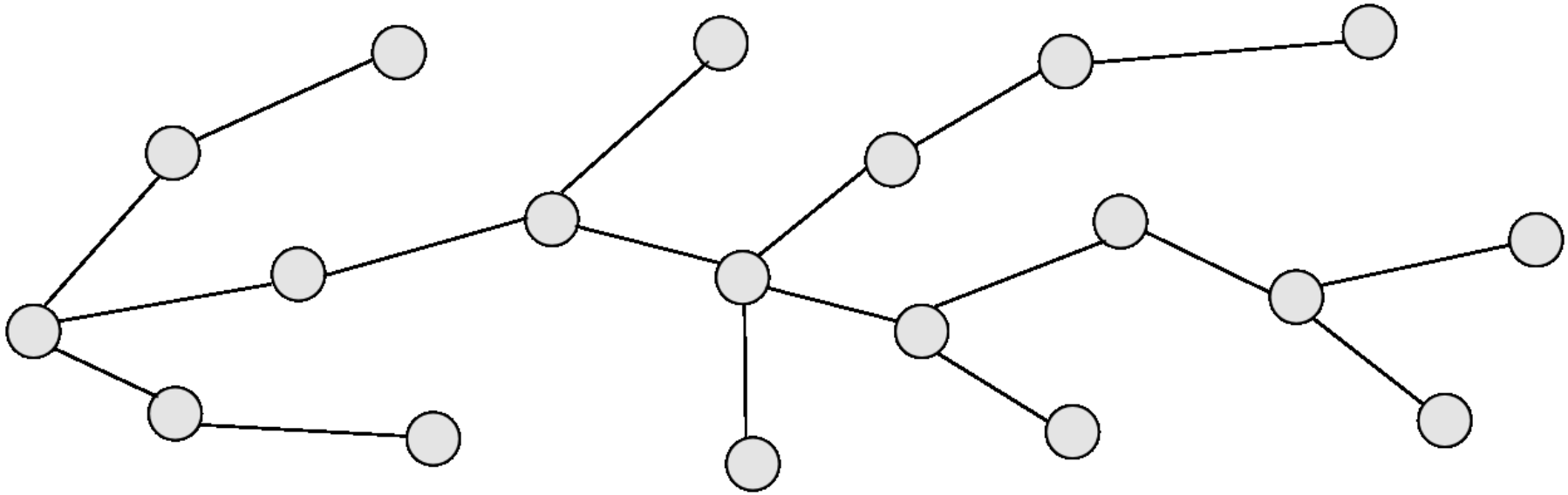
h Broadcast hop limited reached

g Gradient cost not better than MANET entry point cost



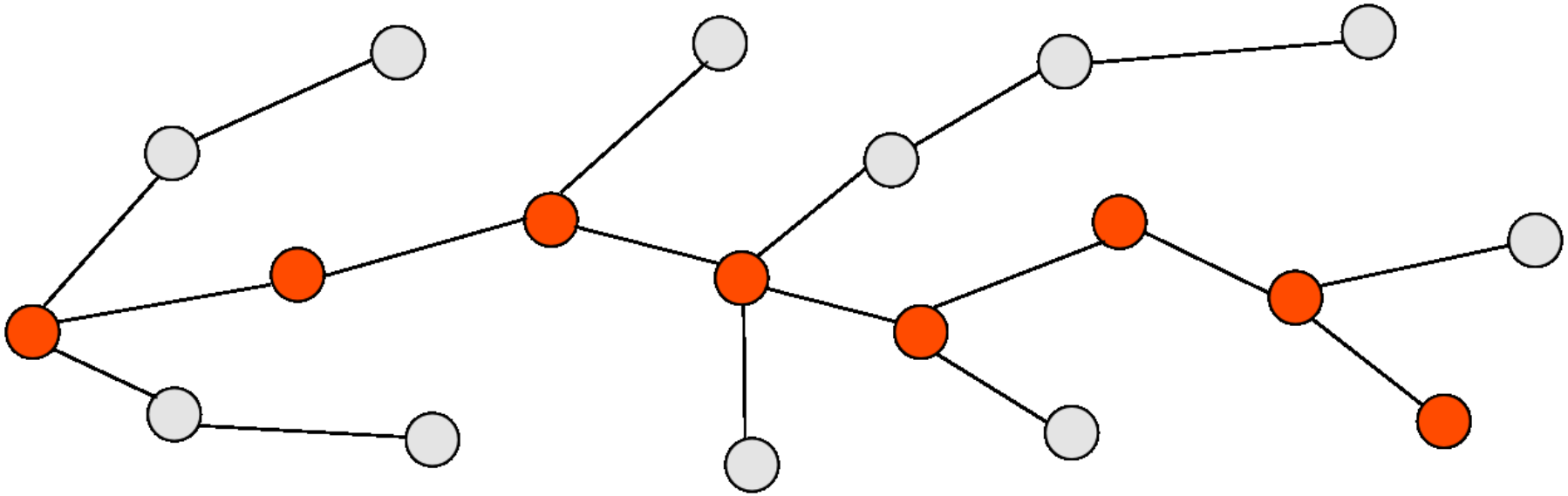
MANET Formation

No urgent packets



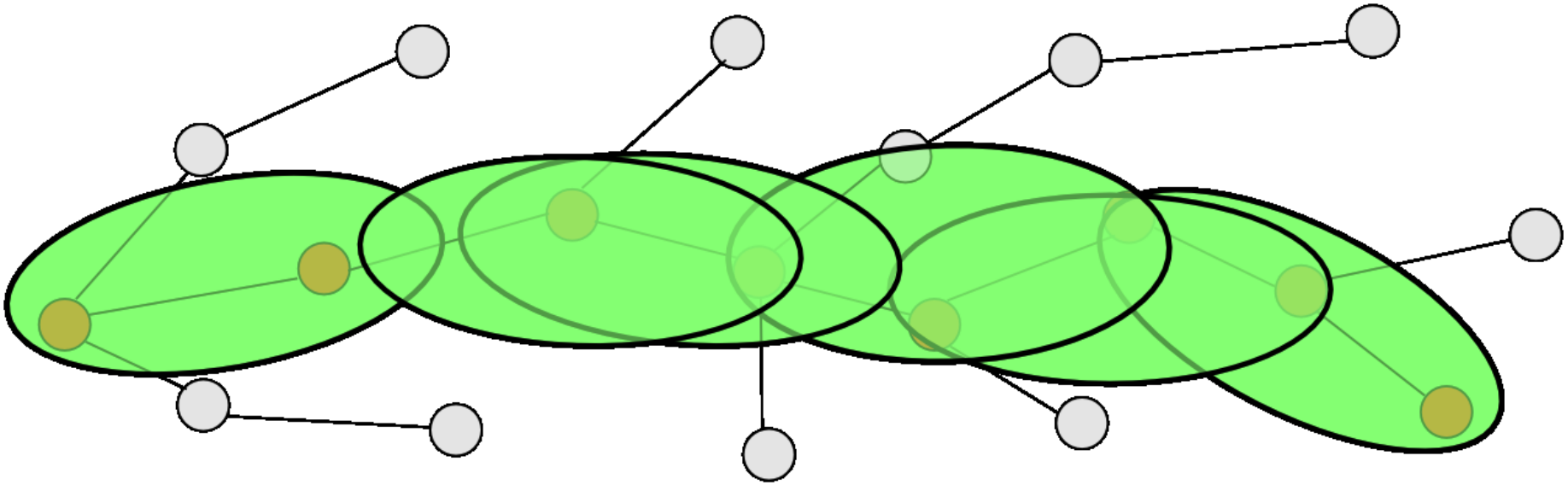
MANET Formation

A urgent packet is routed on the WSN



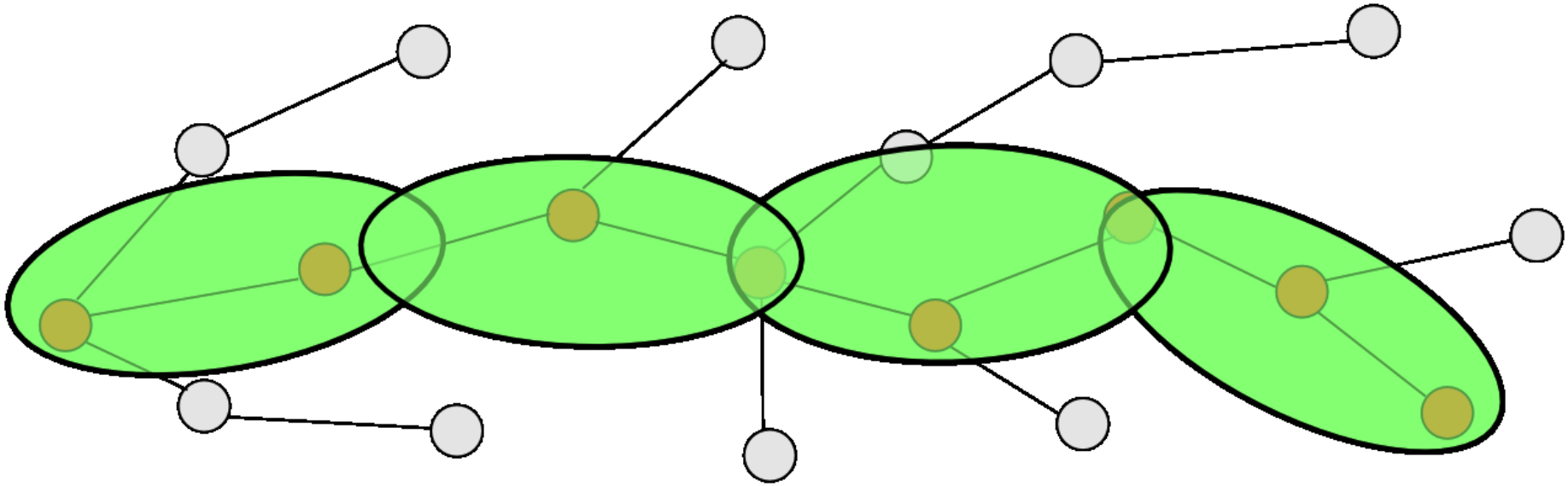
MANET Formation

Multiple MANET cluster form on the urgent packet path



MANET Formation

Overlapping clusters that do not route urgent packet shut down

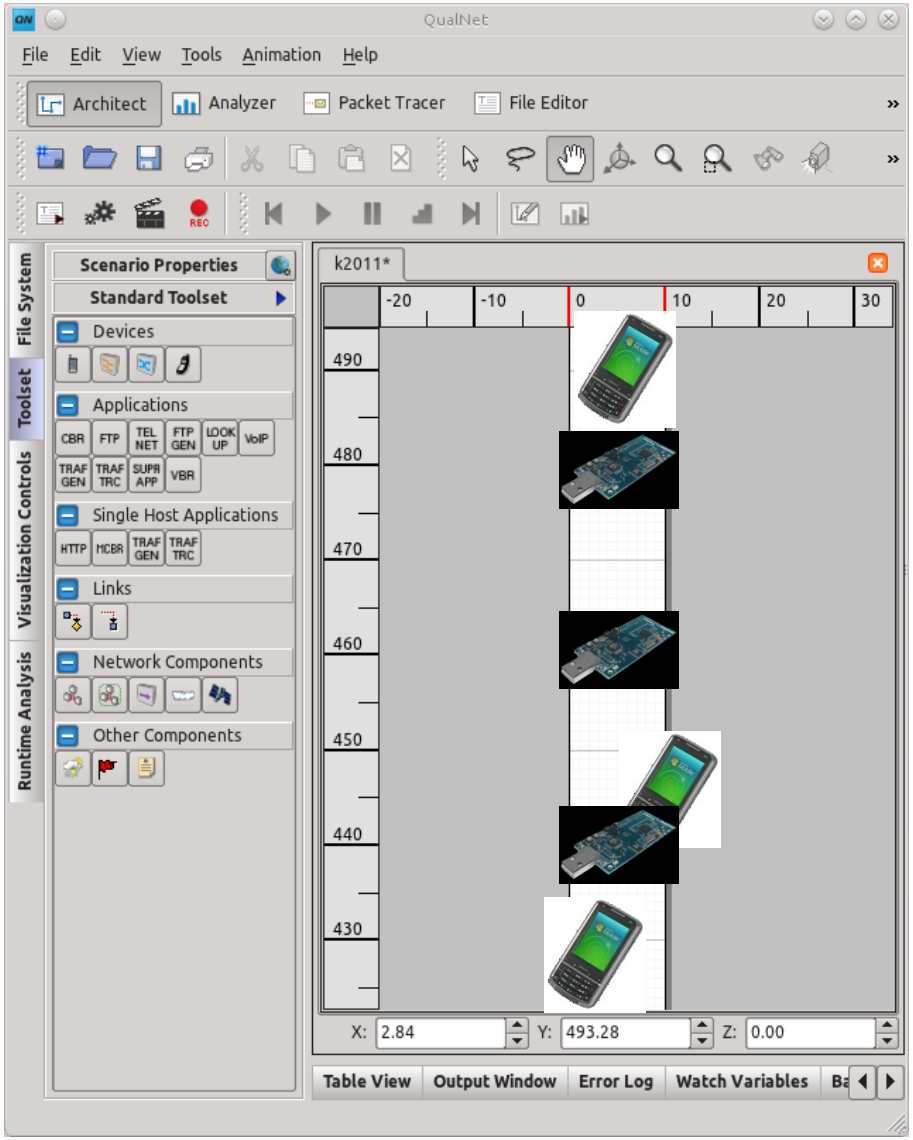


Experimental evaluation

QualNet simulator

- **Street**: 1km long, 10m wide
- **50** equally spaced **sensor nodes** (20m apart)
- From **10** up to **50 MANET nodes**

to simulate a mildly busy road

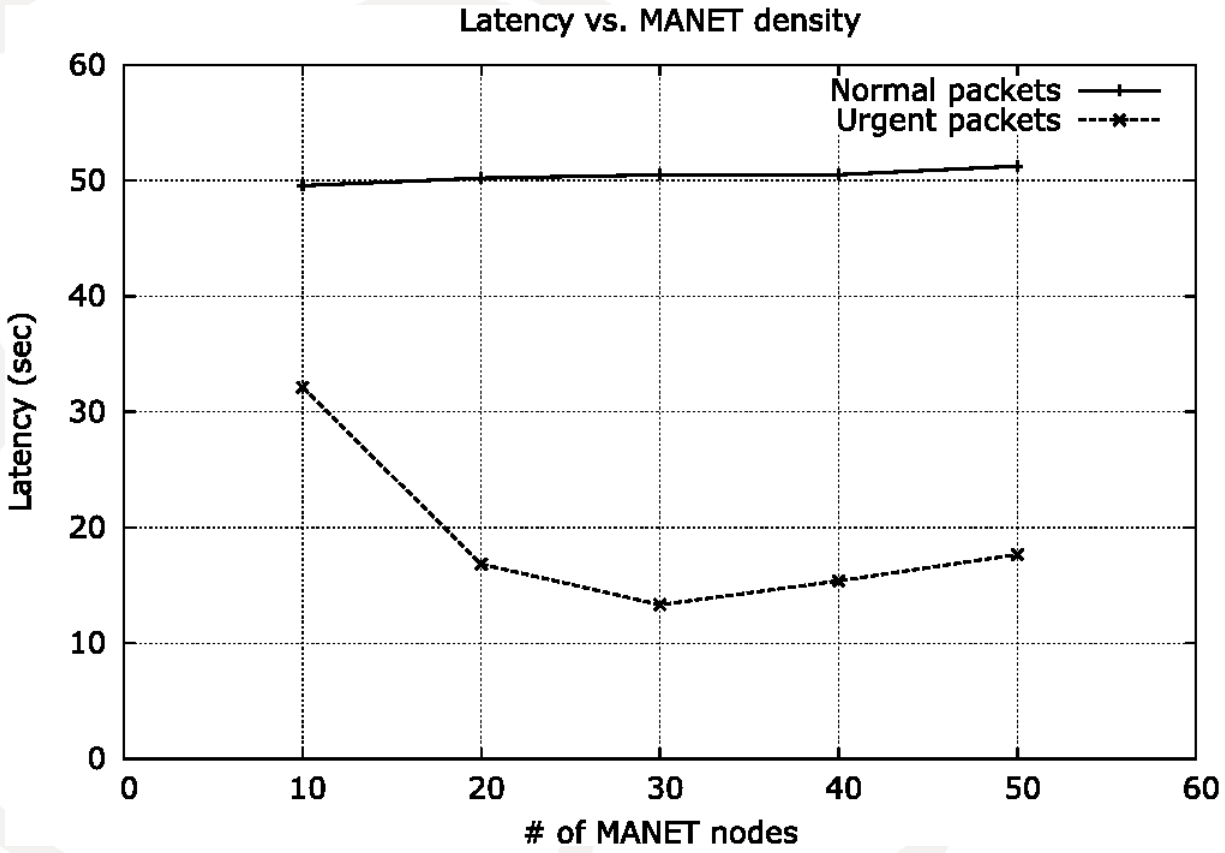


Experimental evaluation

Technical details:

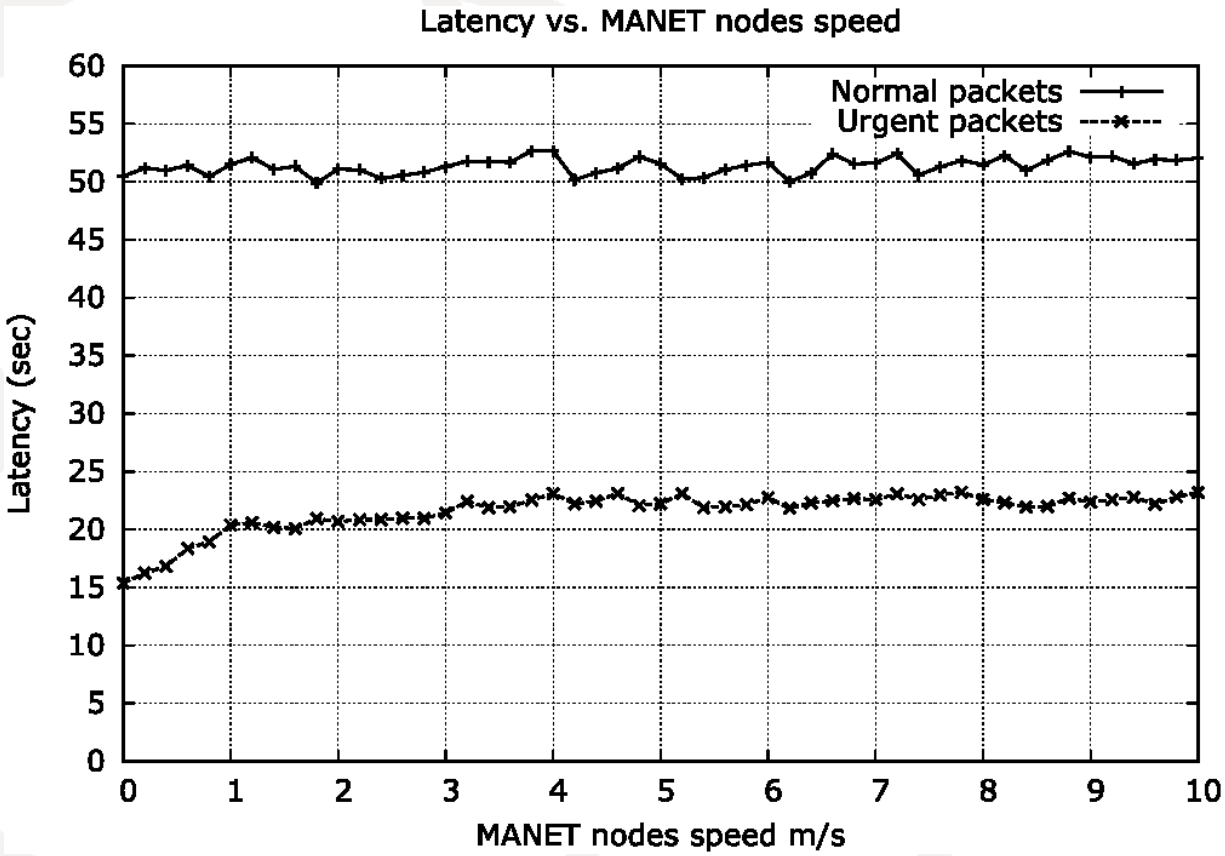
- Sensor nodes
  - Simulate TelosB/MicaZ nodes
  - PHY: 802.15.4
  - MAC: TinyOS CSMA/CA
  - Radio duty cycling: 2.5%
  - Application: TinyOS 2.1 CTP + WHOO
- MANET nodes
  - MANET PHY and MAC: IEEE 802.11b
  - Low-power PHY: 802.15.4
  - Low-power MAC: CSMA/CA
  - Application: WHOO
  - Mobility model: random waypoint

Latency vs. MANET density



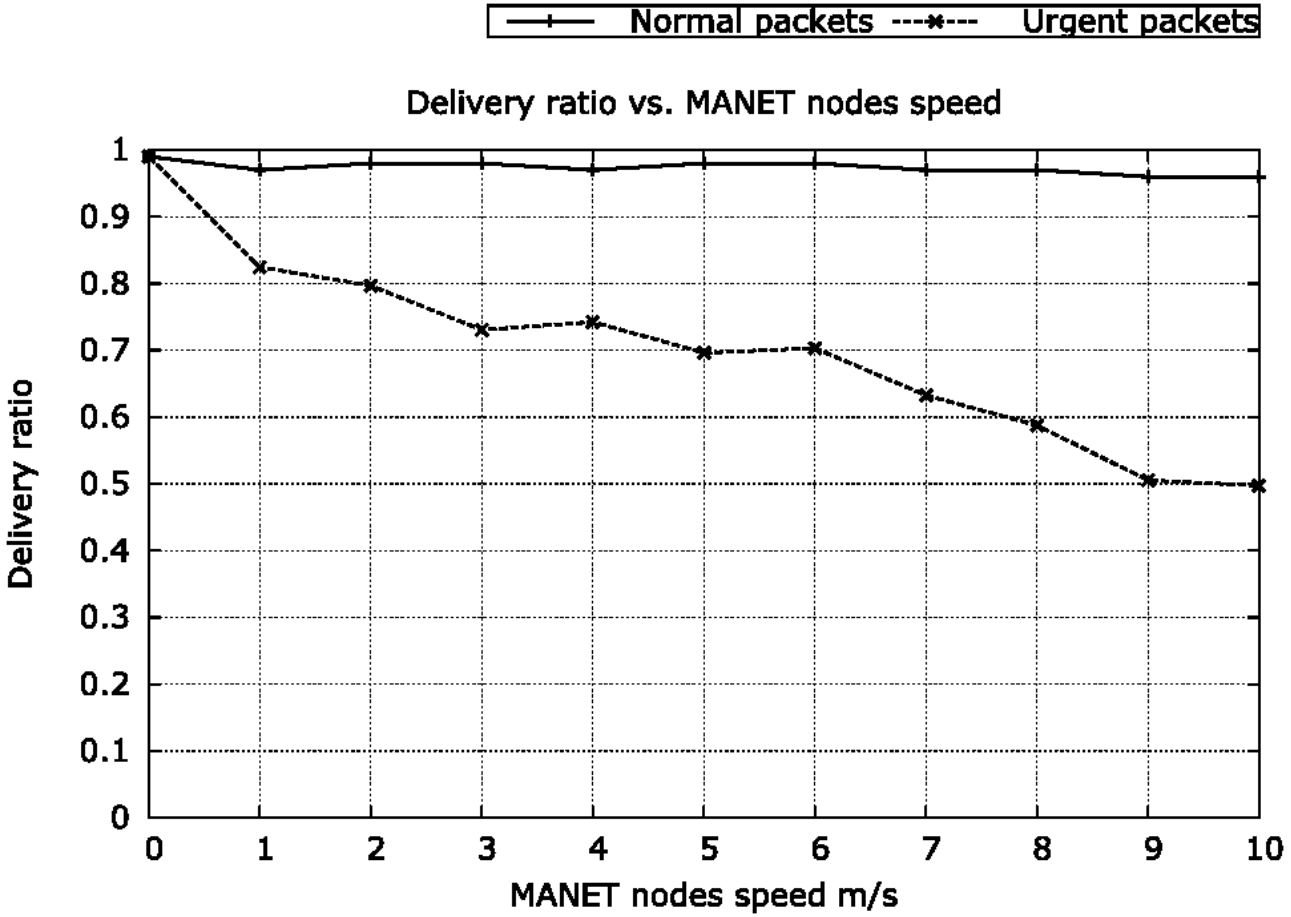
Latency reduced up to 75%

Latency vs. MANET nodes speed



Urgent packet routing independent from MANET nodes speed (for speed > 1 m/s)

Delivery ratio vs. MANET nodes speed



Delivery ratio decreases increasing MANET nodes speed because of broken clusters: **repeated sends** as a remedy

State of standardization

WHOO demonstrates that WSN-MANET integration can be a basic enabler to realize internet of Things (**IoT**), Machine to Machine communication (**M2M**) and **Smart Cities** scenarios

Need for **widely accepted standards**

- There are many competing standards and proposal for different application niches, working at **different layers of the ISO/OSI stack**: ZigBee, Near Field Communication (NFC), Bluetooth Low Energy, DASH7, Wavenis, Z-Wave, …
- Low power protocols are often **cross-layer**: a joint IETF/IEEE effort would help widespread diffusion of low-power wireless interfaces

Conclusion and ongoing research efforts

WHOO: a **hybrid routing protocol** for **WSN** that enables leverage of **mobile devices** to provide high **quality of service**

- Ongoing work:
  - A more proactive approach: cache urgent data, while waiting for a backbone to be available
  - Fine tuning of novel power policies
  - Fine tuning of additional cluster parameters
  - Larger scale tests

WHOO website:
http://www-lia.deis.unibo.it/Research/WHOO/

Contacts:

Giuseppe Cardone
giuseppe.cardone@unibo.it

Questions?