A Framework for Data Collection System with Sensor Networks in Disaster Circumstances

IWWAN2004

Oulu, Finland

June 1, 2004

Takahiro Fujiwara
Enegene Co., Ltd.

Haruka Makie
Shizuoka University

Takashi Watanabe
Shizuoka University

エネジン eneGene

Shizuoka University

Shizuoka University WATANABE-Lab.

Data collection for damage assessment with

- **Sensor Networks**
- **Access Network**

combining cellular and ad hoc technologies.

Outline

1) Background and Objective

2) Review of Data Collection Systems for Disaster

3) Proposed Network Model
   - Sensor Networks
   - Access Network
   - Routing Protocol

4) Experiments and Results

5) Summarizing

1. Background & Objective

- **Motivation**

  Quick, accurate damage assessment information is a critical factor for rescue operation.

- **Objective**

  To develop a data collection system for maintaining connectivity of nodes in a disaster, preventing communication congestion.

2. Data Collection in Disaster

Related work:

System	Object	Data	Communication
SUPLEME [4]	Gas pipeline damage	Seismic motion (SI sensor)	Prioritized telephone lines
LIFELINE [5]	Lifelines damage	lifeline meters	Hierarchical wireless
IAA	Persons' safety	Data input by people	Internet
ECCA [7]	– Hybrid configuration: Cellular + Ad hoc – Acquires damage data from residences.		

3. Proposed Network

- **Requirements for Operation:**
  - **Detection of damage**
  - **Transmission of urgent information**
  - **Assessment of hazard**

- **Current Network Conditions:**
  - **Focusing on best-effort performance rather than reliable communications.**
  - **Communication congestion problem even in 3G/4G system.**

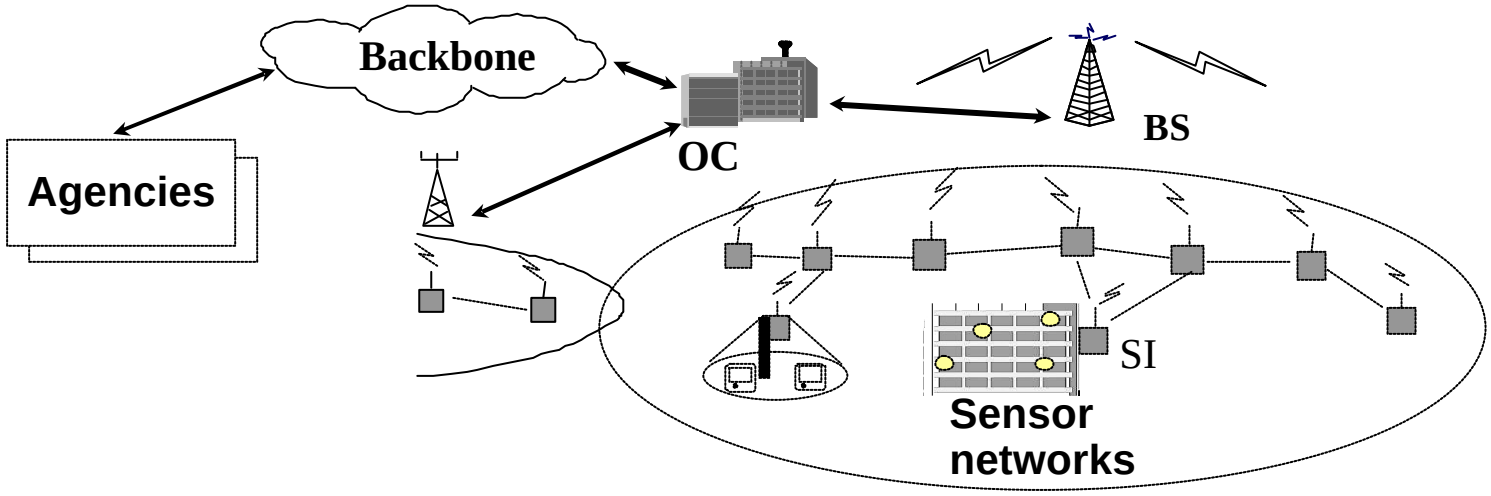
3.1 Network Concept

- **Sensor Networks**

  To acquire damage information with sensors or ubiquitous devices.

- **Access Network**

  To transmit the data to BS and OC.

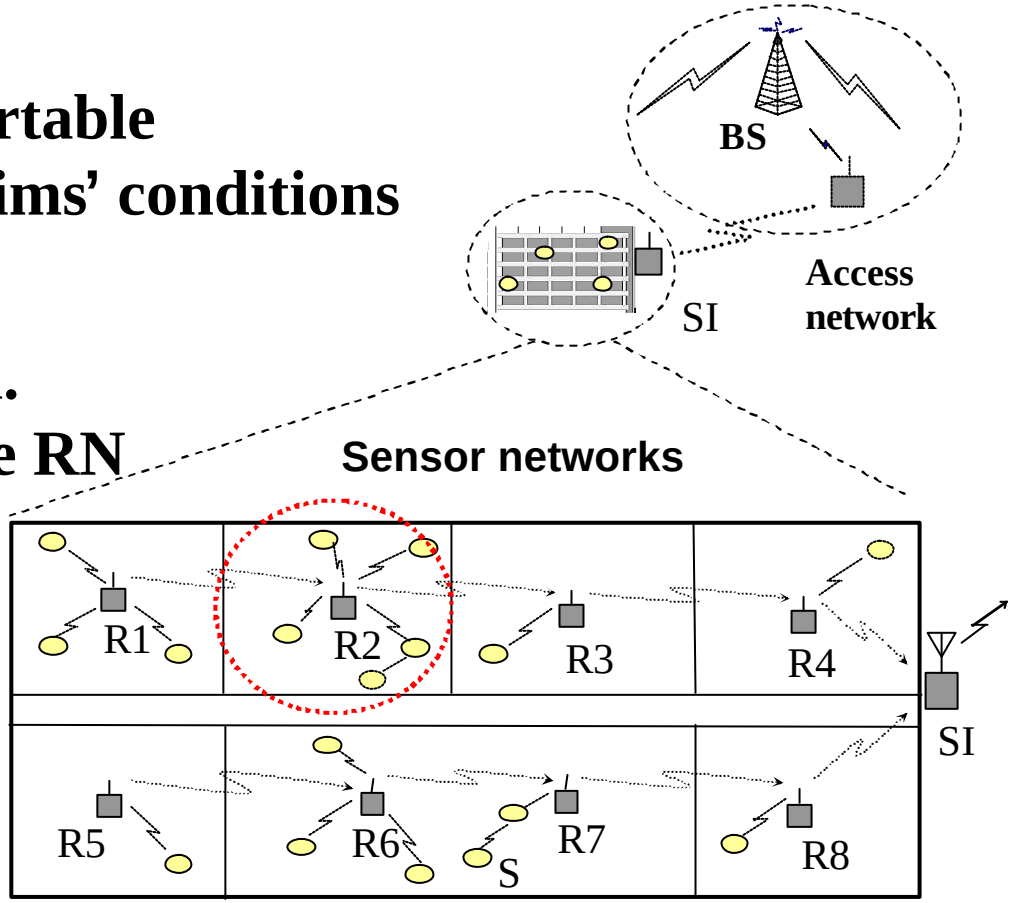


3.2 Sensor Networks (1)

- **Requirements:**
  - Detecting damage
  - Locating of sensors or portable devices
  - Collecting data to a sink node
  - Saving node energy
- **Network Scheme:**
  - Hybrid networking model for multihopping
  - Unicast-based routing protocol, instead of broadcasting.

Sensor Networks (2)

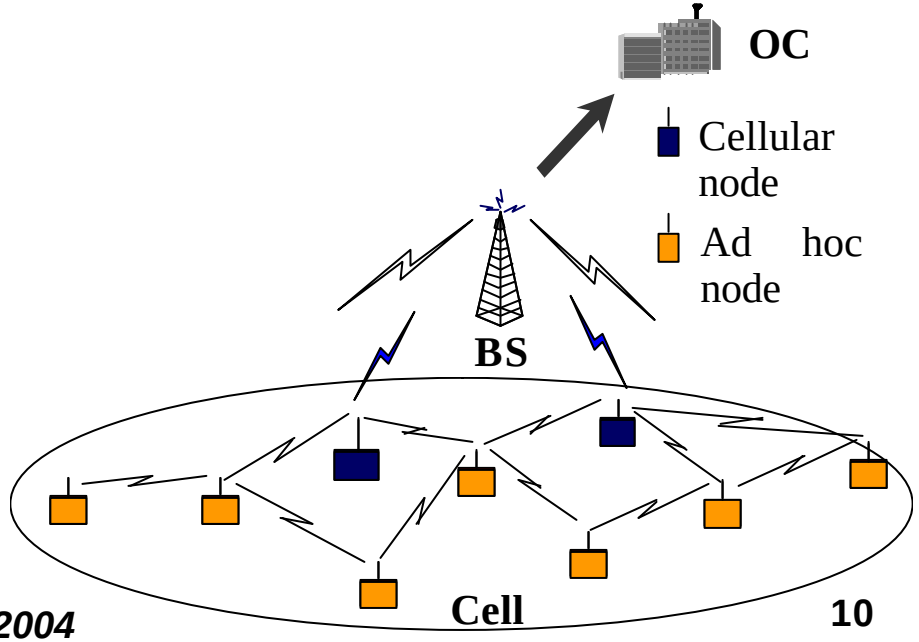
- **Operation:**
  - **SN (Sensor Nodes):**
    - Placed in rooms or portable
    - Detect damage or victims' conditions
  - **RN (Relay Node):**
    - Installed in each room.
    - Add the location of the RN on the packet
  - **SI (Sink Node):**
    - Acquires the location of SN by the info of RN.



SI: Sink node, R: Relay node, S: Sensor node

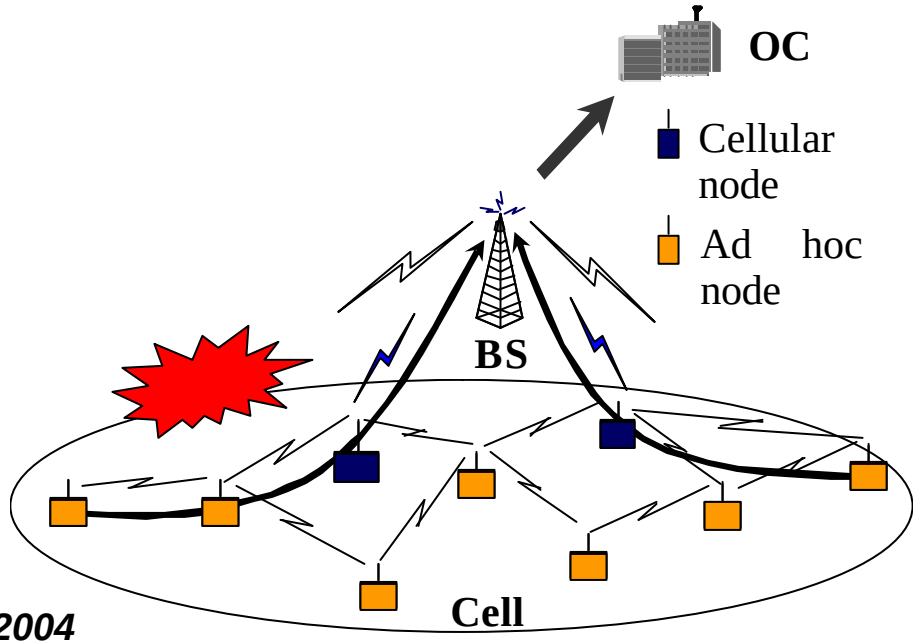
3.3 Access Network

- **Configuration:**
  - **Cellular Network:**
    - Directly connects nodes with the BS, and forwards data to the OC.
  - **Ad hoc Networks:**
    - Connect between nodes by multihopping.



3.3 Access Network

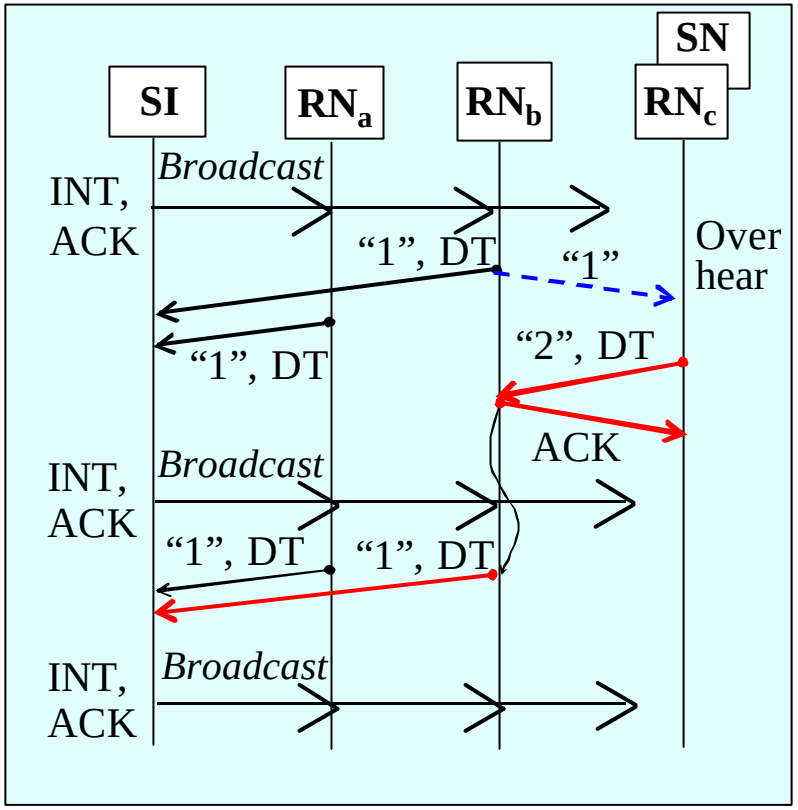
- **Configuration:**
  - **Cellular Network:**
    - Directly connects nodes with the BS, and forwards data to the OC.
  - **Ad hoc Networks:**
    - Connect between nodes by multihopping.
- **Operation:**
  - Switching the mode from **cellular** to **ad hoc.**
  - Discovering a route, transmitting a packet to the neighbor.
  - Relaying the packet to BS.



3.4 Routing Protocol (1)

Sensor Networks

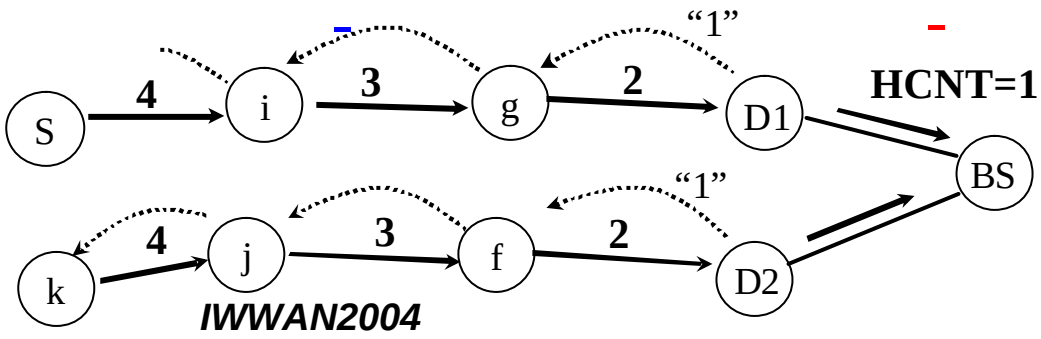
1. **SI: Periodically broadcasts interrogation (INT).**
2. **Accessible nodes (RN):**
   - **Transmit a data packet, including Hop-Count (HCNT).**
3. **Inaccessible nodes (RN/SN):**
   - **Monitor other nodes' packets.**
   - **Check the HCNT, send data by unicasting, increasing the HCNT.**
4. **The intermediate node:**
   - **Replies ACK.**
   - **Relays the packet via a previously known route.**



Routing Protocol (2)

- **Access Network**
  - **Direct connection nodes (DCNs):**
    - **Transmit a packet to BS periodically with a direct path, setting Hop-count (HCNT) at one (1).**
  - **Inaccessible nodes:**
    - **Monitor the surrounding communications, and check the HCNT.**
    - **Discover a node accessible to BS, transmit a packet by unicasting, increasing HCNT.**

➔Unicast-based routing protocol for multihopping



3.5 Summary on Routing Protocol

- **Same scheme in Sensor and Access networks**:
  - **Monitoring communications**
  - **Accessing by unicasting**

- **Unicast-based access to reduce extra transmission for power saving.**

4. Experiments & Results

- **Metrics :**
  - **Reachability**
    - **Rate of nodes to be able to build a route and to access the destination by a direct link or multihopping.**

$$Reachability = \frac{\text{The number of reachable nodes to the destination}}{\text{Total number of nodes}}$$

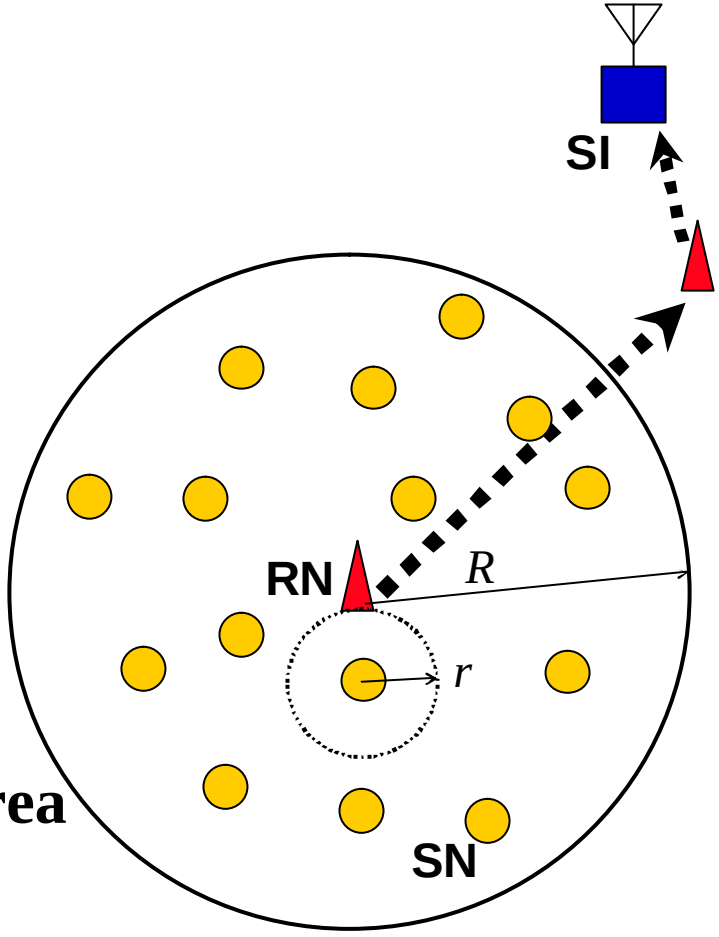
$$= \frac{\sum_{i=1}^{k} m_i}{N}$$

m_i : Number of nodes reachable at i hops

N : Total number of nodes

4.1 Sensor Networks

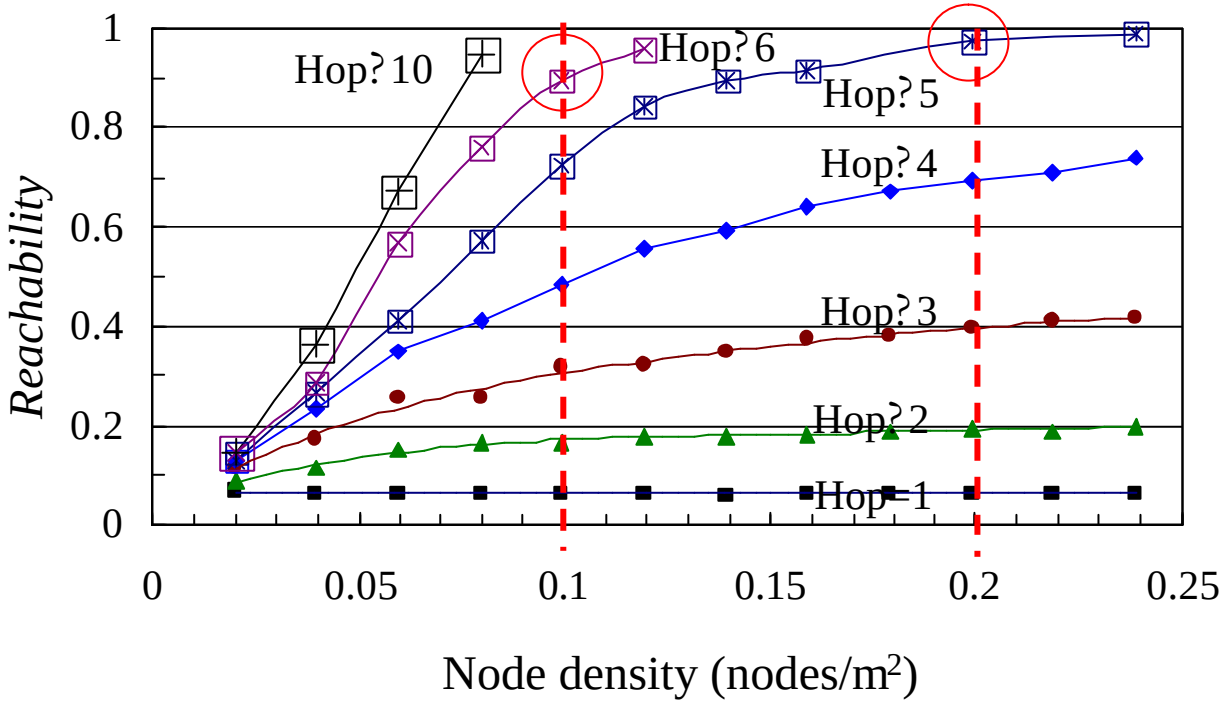
- **Simulation model:**
  - **Arrangement:**
    - **SNs: arranged randomly within the range of RN (*R*).**
    - **RN: installed in advance to reach SI.**
  - **Condition:**
    - **Range : *R* = 20m, *r* = 5m**
    - **Node density : 25 - 300 nodes/area**
    - **Fixed limit of HCNT: £10 hops**



Reachability of Sensor Networks

Conditions:

- **Number of nodes: 25 - 300**
- **Area of RN-range: 1257m² (*R*=20m)**



- **Multihopping ³ 6 hops, Node density ³ 0.1,**

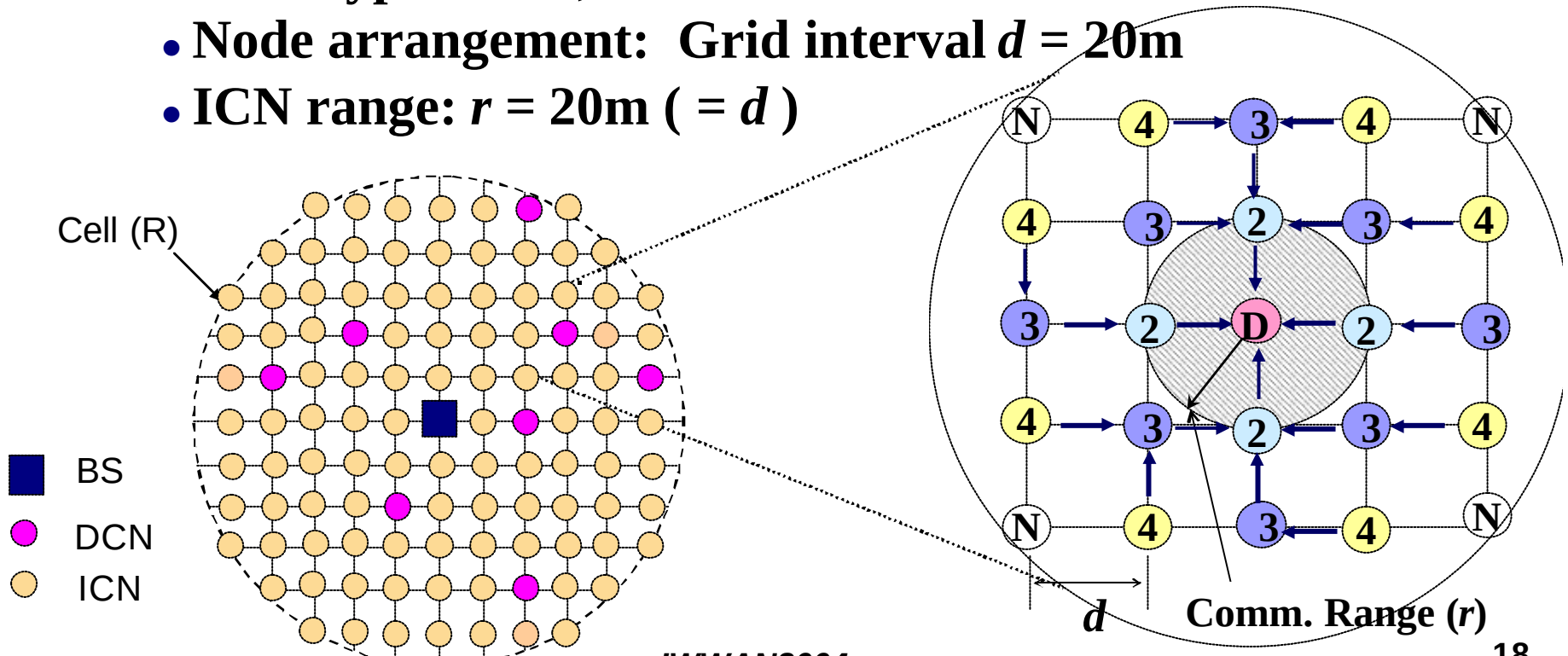
➔Reachability ³ 90%

4.2 Access Network

Simulation Model:

Conditions:

- Cell size: R
- Node type: DCN, ICN
- Node arrangement: Grid interval d = 20m
- ICN range: r = 20m (= d)

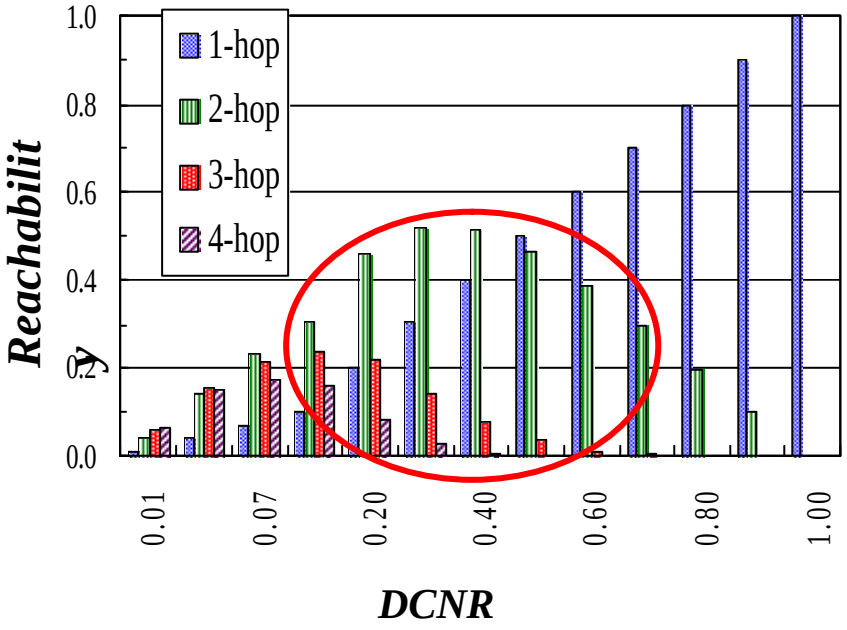


Reachability of Access Network

Condition: R = 340m, Node = 901

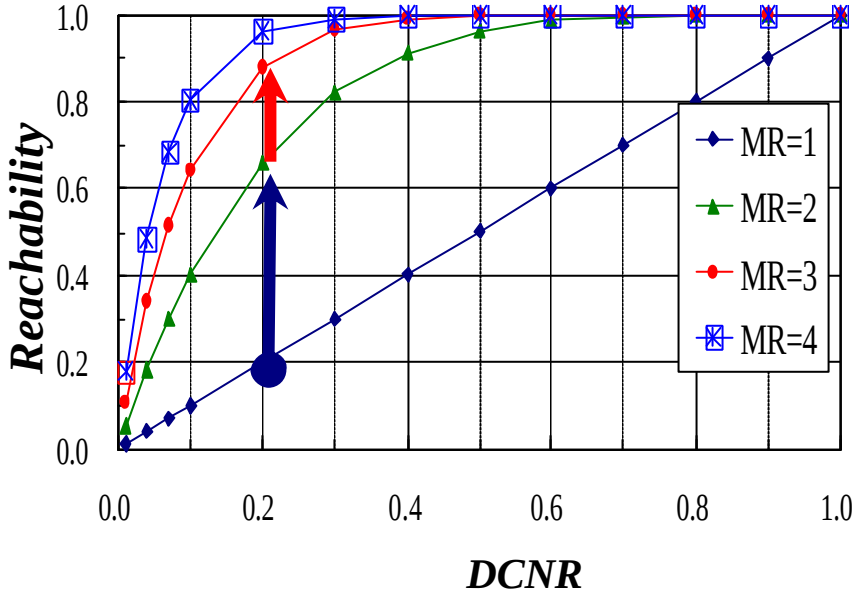
$$DCNR = \frac{Number\ of\ direct\ connection\ nodes}{Total\ number\ of\ nodes\ in\ a\ cell} = \frac{m_1}{N}$$

Reachability in each hop-count



Dominant : 2- and 3-hop

Reachability in cumulative form



Reachability : required hops ? 3.

Summary

- **Integrated data collection system for disaster**
  - **Sensor networks**
  - **Access network**
- **Capable of achieving high reachability in a small number of hops even in disaster circumstances, and collecting damage assessment information in a whole city.**
- **Future work:**
  - **Evaluation for the total performance of the integrated network, and effectivity of node locating and energy saving methods.**

Thank you