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A New Task Based Approach for Supporting Distributed Applications on Mobile Ad Hoc Networks

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Mobile Ad Hoc Network of Devices

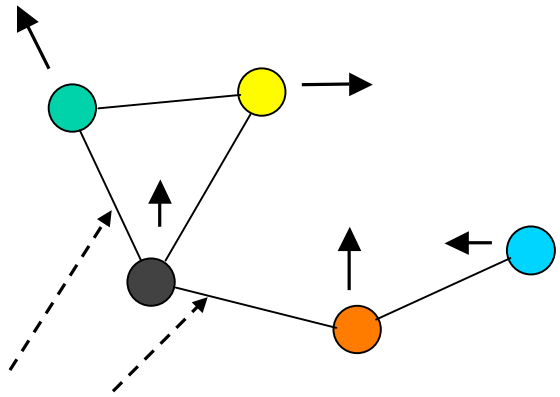
MANET

Specialized / Multi-purpose

computing devices

provide *services* to other devices

direction of motion

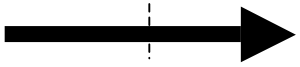


wireless links

Channel Access: CSMA/CA or Slotted

Multi-hop Routing: AODV,DSR …

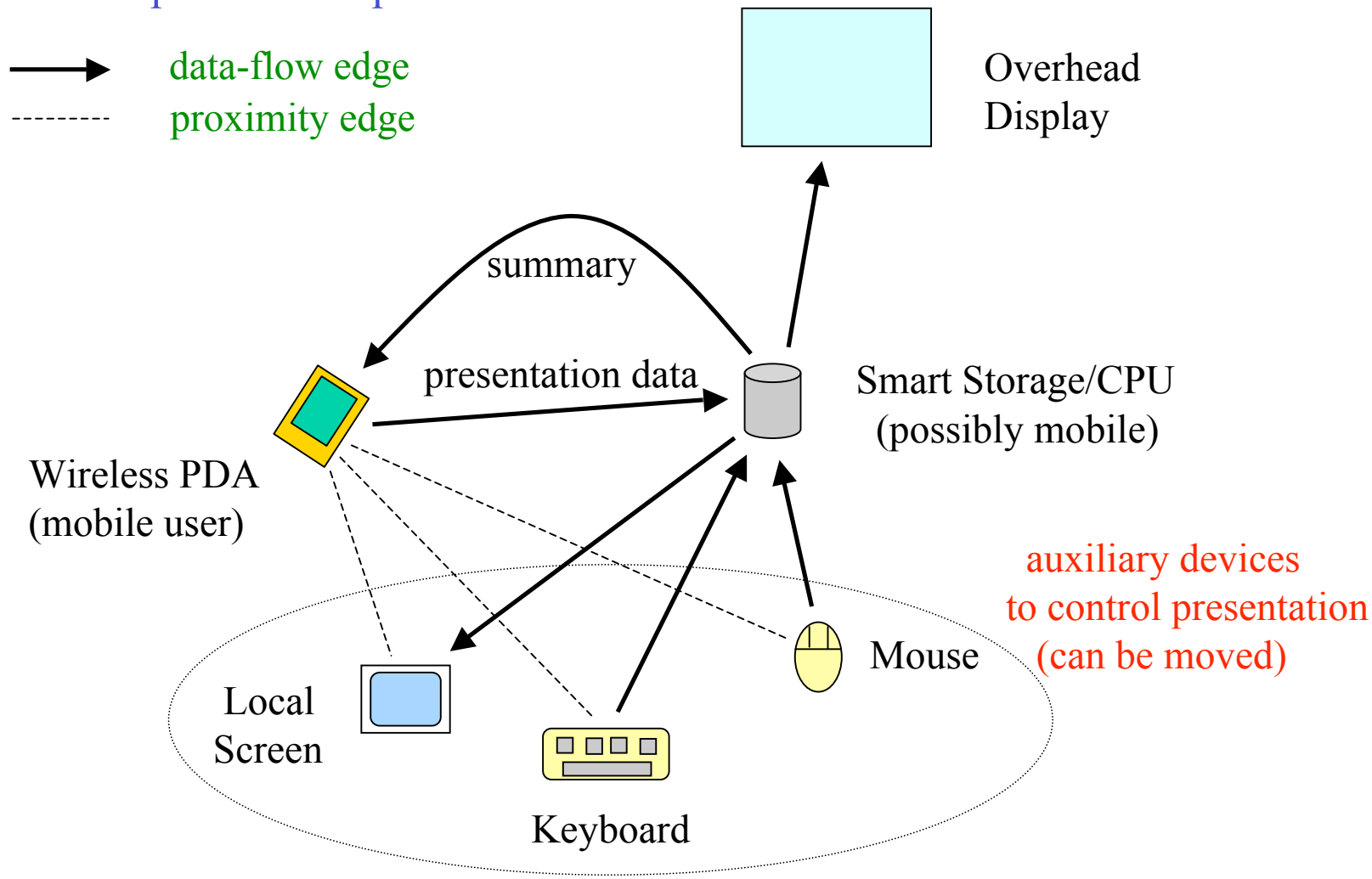
at time t_0



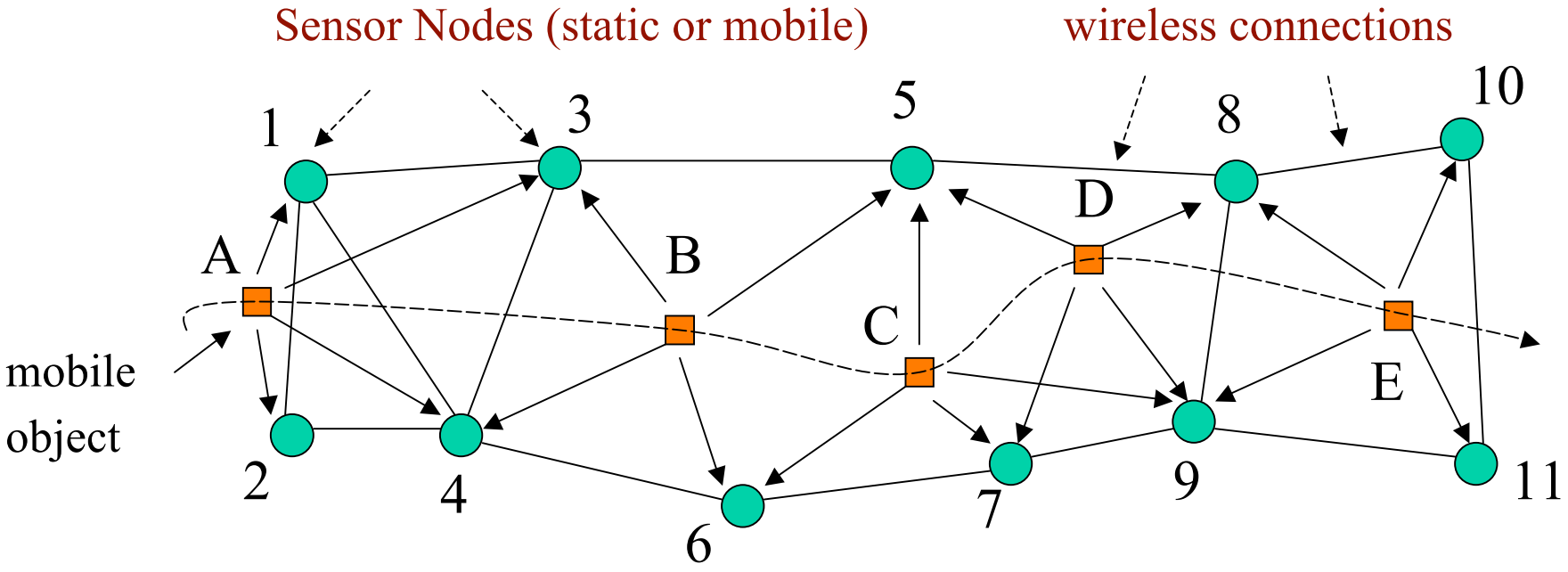
at time $t_0 + \Delta$

A Smart Presentation Application

The user does not care which *particular* devices perform the presentation

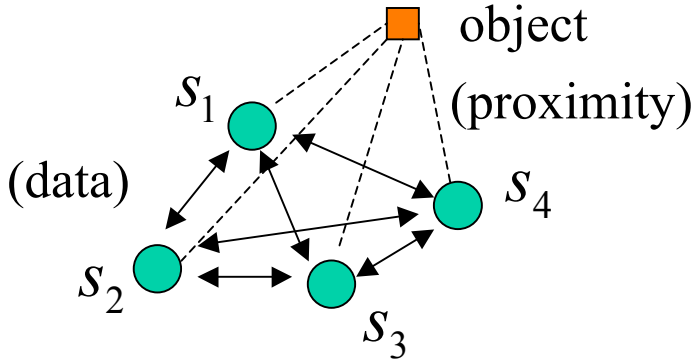


Optimal Sensing in Sensor Networks



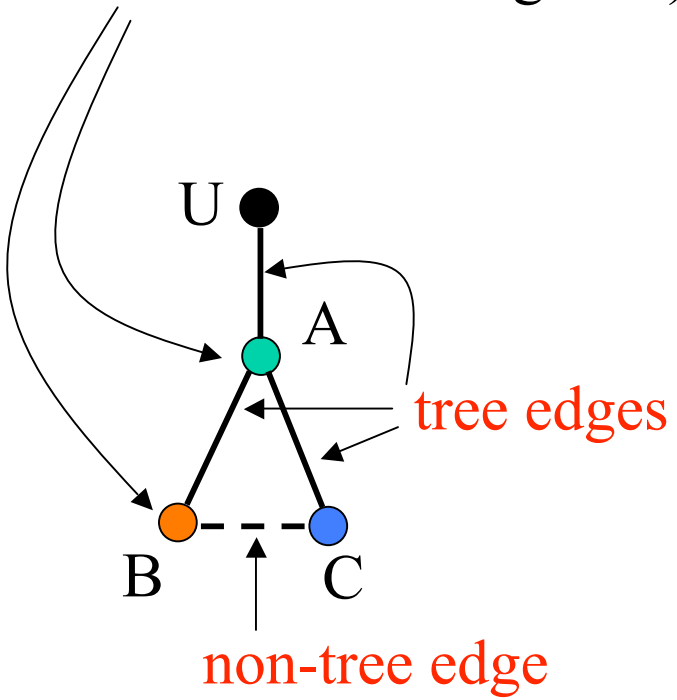
Position	Optimal Sensors
A	{1,2,3,4}
B	{3,4,5,6}
C	{5,6,7,9}
D	{5,7,8,9}
E	{8,9,10,11}

Sensing Graph



Task Graphs and Embedding

nodes (colors indicate distinct device categories)



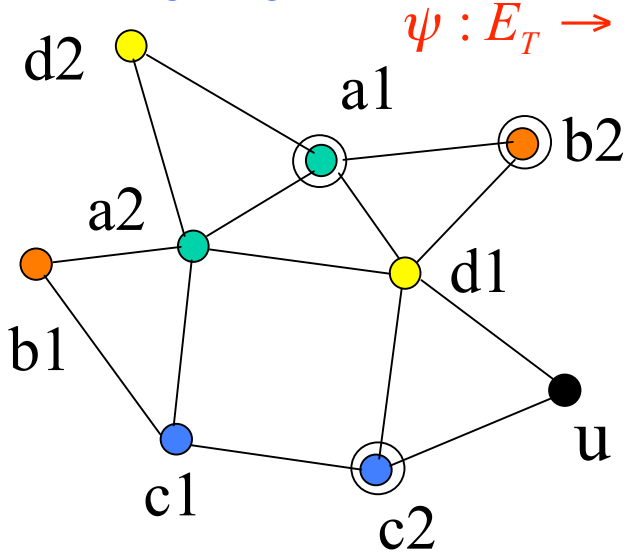
Task Graph

$TG = (V_T, E_T)$

$G = (V_G, E_G)$

$\varphi : V_T \rightarrow V_G$

$\psi : E_T \rightarrow P_G$ (Paths in G)

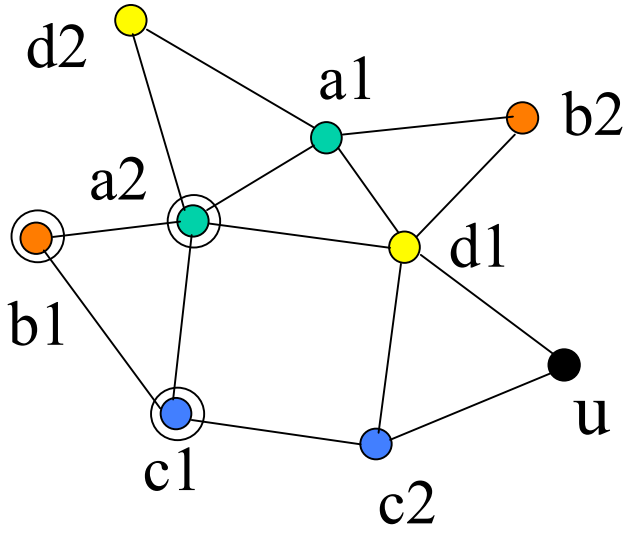


Embedding 1

A→a1

B→b2

C→c2



Embedding 2

A→a2

B→b1

C→c1

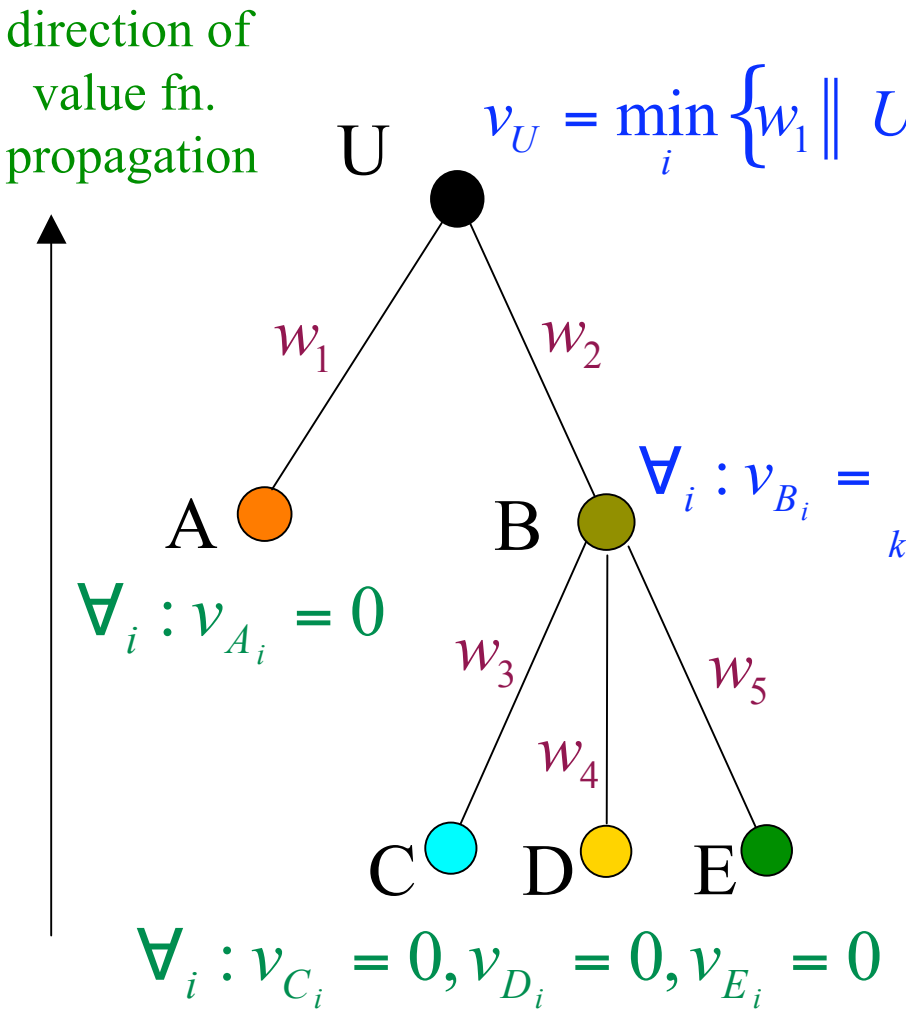
Optimization Problem Formulation

- Given:
  - MANET (at some instant): $G = (V_G, E_G)$
  - Task Graph: $TG = (V_T, E_T)$
  - Weight function: $w : E_T \rightarrow \Re^+$

- Find mappings $\varphi : V_T \rightarrow V_G$ and $\psi : E_T \rightarrow P_G$ such that Average Dilation is *minimized*:

$$D_{avg} = \frac{1}{\sum_{e \in E_T} w(e)} \sum_{e=(x,y) \in E_T} w(e) \, \| \varphi(x), \varphi(y) \|_G$$

Optimal Algorithm for *Tree* TGs



$$v_U = \min_i \left\{ w_1 \| U, A_i \|_G \right\} + \min_i \left\{ v_{B_i} + w_2 \| U, B_i \|_G \right\}$$

$$\forall_i : v_{B_i} = \sum_{k \in \Gamma_B} \left[\min_j \left\{ v_{k_j} + w_{B,k} \| B_i, k_j \|_G \right\} \right]$$

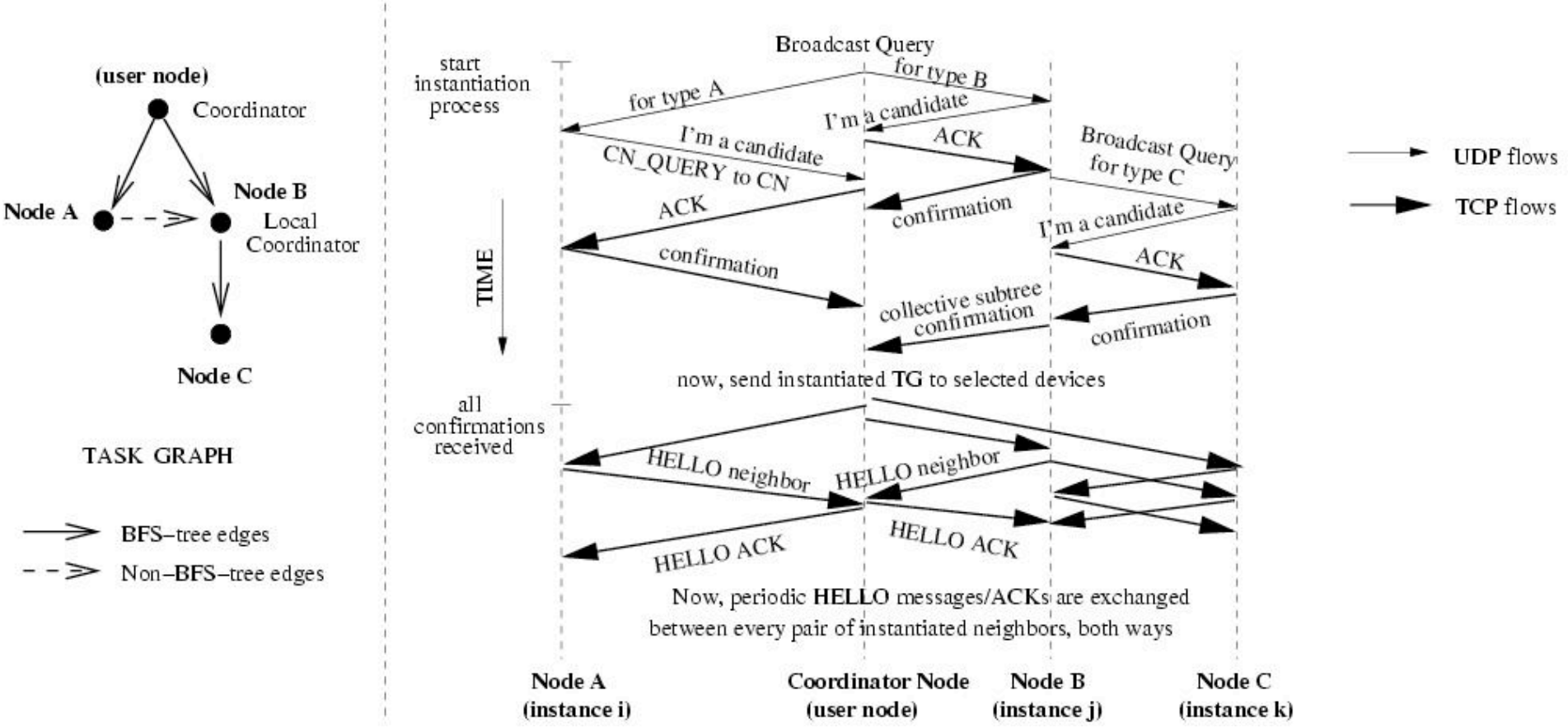
$U, A_i, B_i, C_i, D_i, E_i \in V_G, \forall_i$

$v : V_G \Rightarrow \Re^+$ (value fn.)

$w : E_H \Rightarrow \Re^+$ (weights)

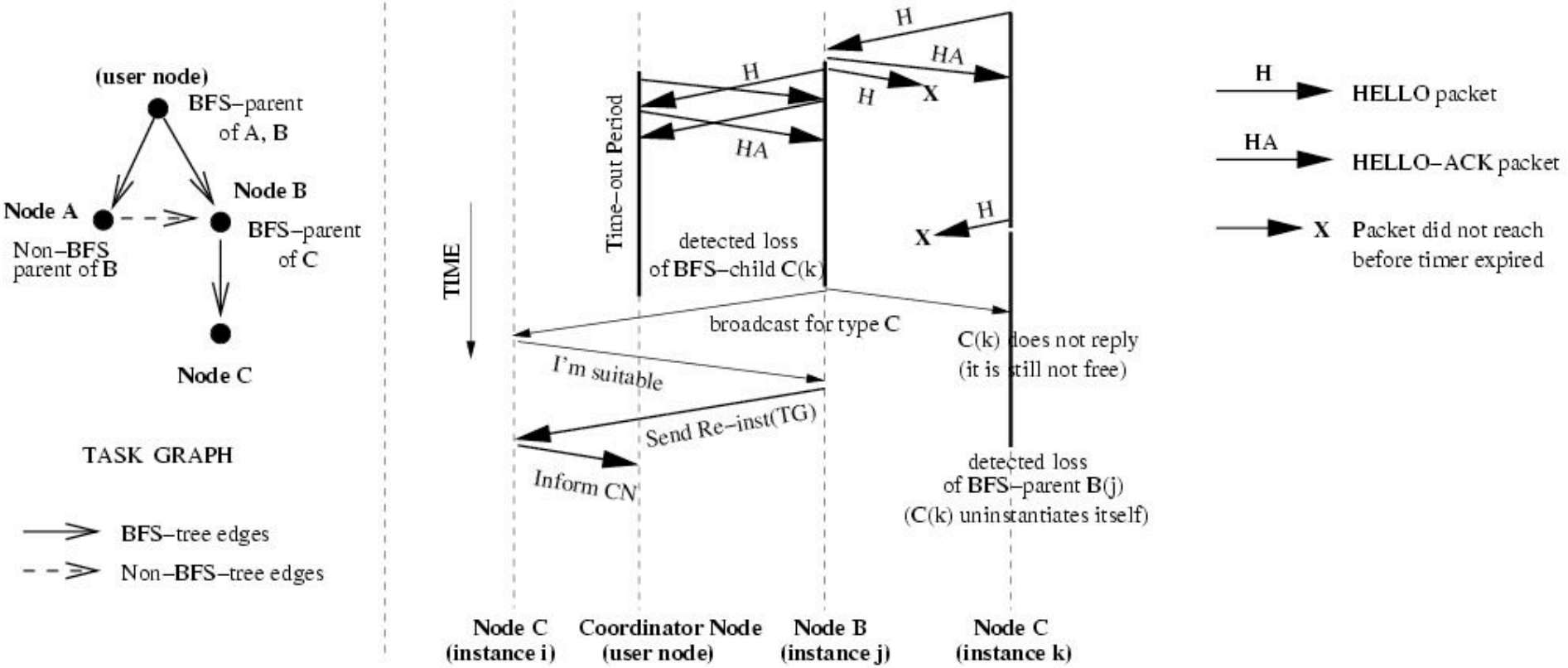
$\Gamma_B = \{C, D, E\}$

Distributed Heuristic Algorithm



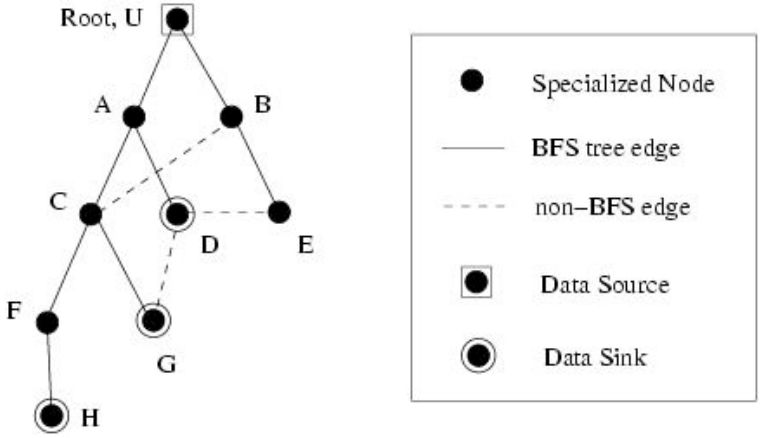
- Instantiation proceeds from the root of TG
- Algorithm is simpler and more practical for MANETs
- Only *local* device instances are involved

Disruption Detection and Recovery

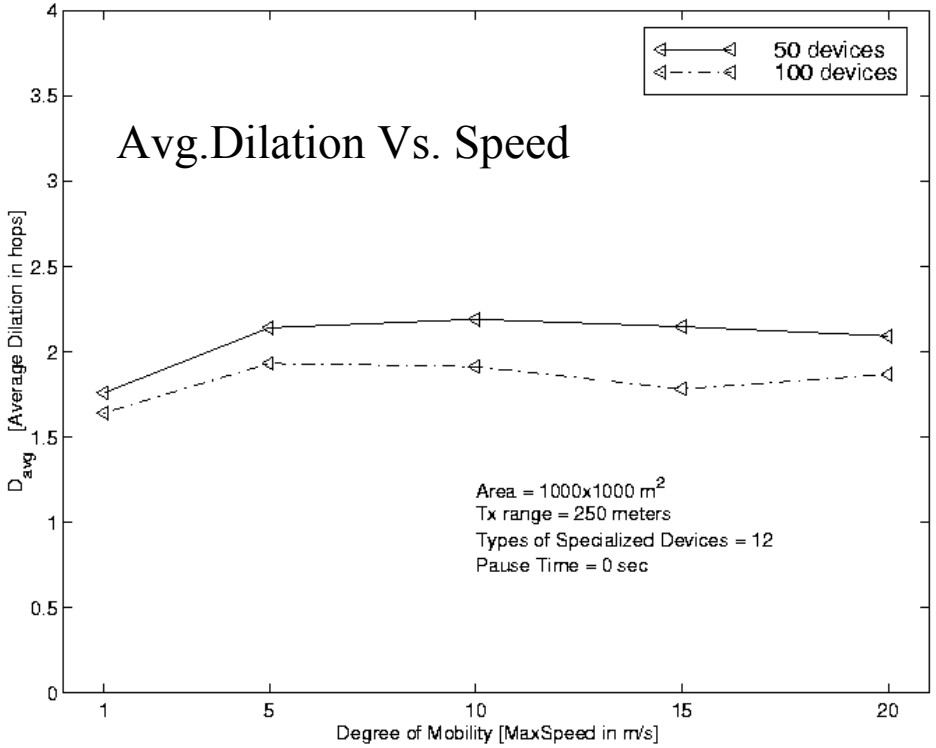


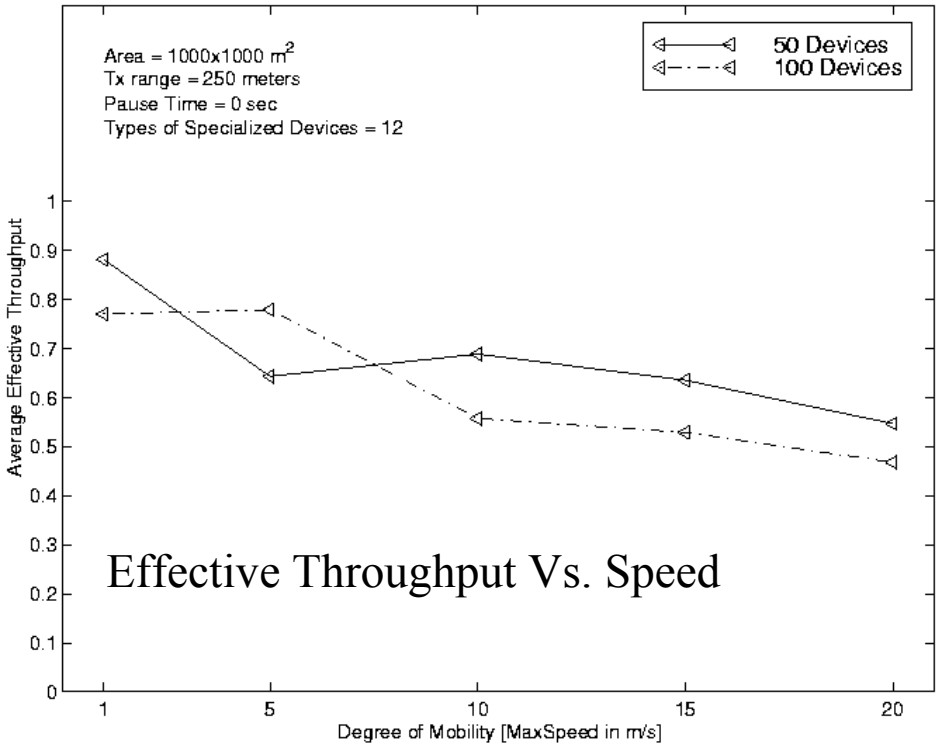
- Each node instance detects disconnections from logical neighbors.
- HELLO-ACK doesn't arrive in time ➔ Disconnection is detected
- Only BFS-parent instances perform re-instantiation of children.

Simulation Results



- U sends 12500 bytes / 5sec
- 1000 meters x 1000 meters
- N = 50, 100
- 12 Device Categories
- Speed: 1,5,10,15,20 m/s
- Constant Mobility
- Tx Range = 250m





Contributions and Significance

- Algorithms and protocols that exploit the *nature* and *requirements* of a given distributed task for discovering *suitable* devices for cooperative execution of the task.
  - First step towards efficient, dynamic execution of complex distributed tasks on a collection of mobile devices.
  - Each device is capable of performing simpler tasks.
- Algorithms detect and adapt to network partitions which may be caused by mobility of devices.
- Decoupling a service from a particular device address is desirable in mobile failure-prone environments.
- Enables seamless execution of ubiquitous computing tasks.
- Enables harnessing of distributed computing power in an infrastructure-less environment.