MOBILE WIRELESS SENSOR NETWORK

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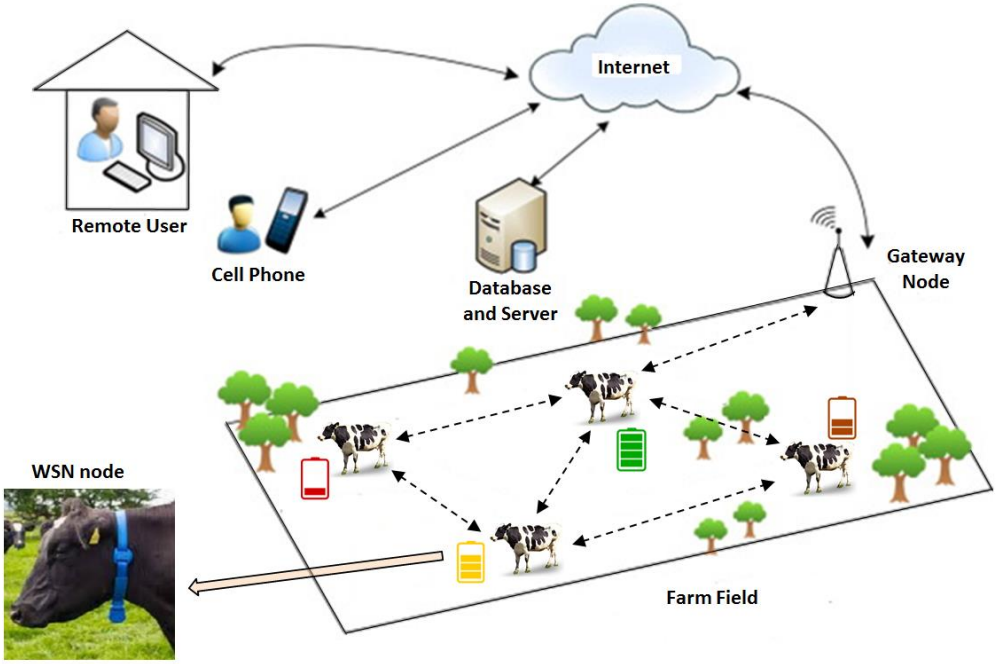
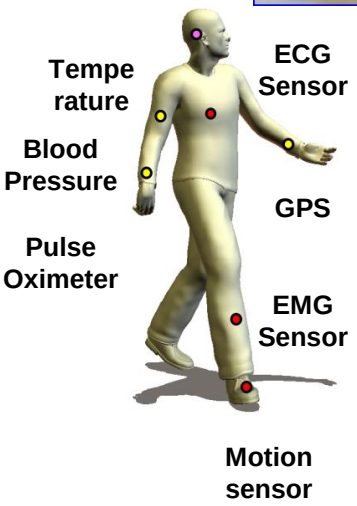
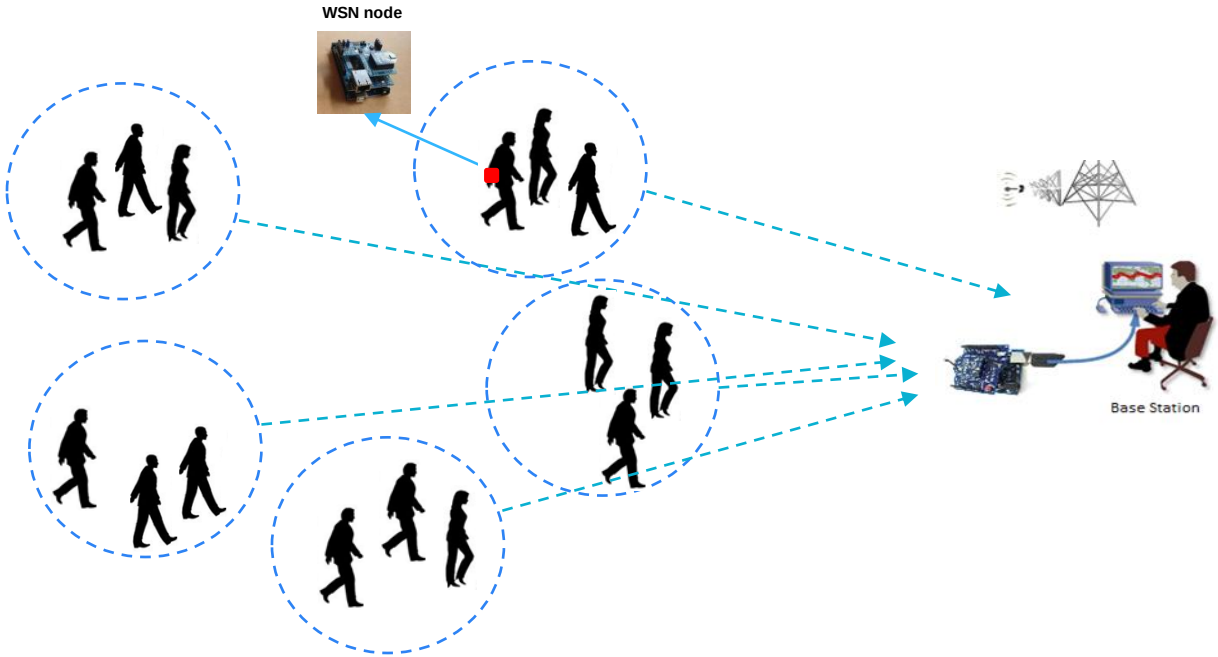
Motivation: Wireless Sensor Networks (WSN)



- Formed by hundreds or thousands of motes that communicate with each other and pass data along from one to another.
- Applications with considering group mobility:
  - Animal Monitoring
  - Search-and-Rescue Operations
  - Healthcare Monitoring
  - Evacuation Systems

Evacuation System





- In natural disaster, people will move in a group to go to a safe area.
- It allows a dynamic group change when a person moves to other groups.

Evacuation Parameters

Evacuation Time Results [2]

Evacuation Time	Survivors	Death/Missing
Immediately	14% (71)	10% (36)
1-5 minutes	17% (84)	7% (23)
6-10 minutes	19% (94)	11% (38)
11-20 minutes	17% (87)	8% (28)
21-30 minutes	11% (56)	9% (32)
31-60 minutes	8% (42)	6% (20)
61-120 minutes	2% (9)	1% (2)
More than 120 minutes	1% (4)	1% (2)
No evacuation	11% (58)	48% (170)
Total	100% (505)	100% (351)

Evacuation Time Scale [2]

Evacuation Time	Scale
Immediately	9
Within 5 minutes	8
Within 10 minutes	7
Within 20 minutes	6
Within 30 minutes	5
Within 60 minutes	4
Within 120 minutes	3
More than 120 minutes	2
No evacuation	1

Crucial Time

Walking Speed of Evacuees [3]

Density	Fast walkers	Slow Walkers
Less than 2 people/m2	2.0m/sec	0.5 m/sec
2-3 people/m2	1.5m/sec	0.375 m/sec
3-4 people/m2	1.0m/sec	0.25 m/sec
More than 4 people/m2	0.75m/sec	0.189 m/sec

Speed of Evacuees [4]

Type	Average Speed	Max Speed
Pedestrian	1.10 m/s	1.33 m/s
Car	5.03 m/s	8.33 m/s

The Issues

Problem Definition

A Dynamic Group Change for Group Mobility Applications

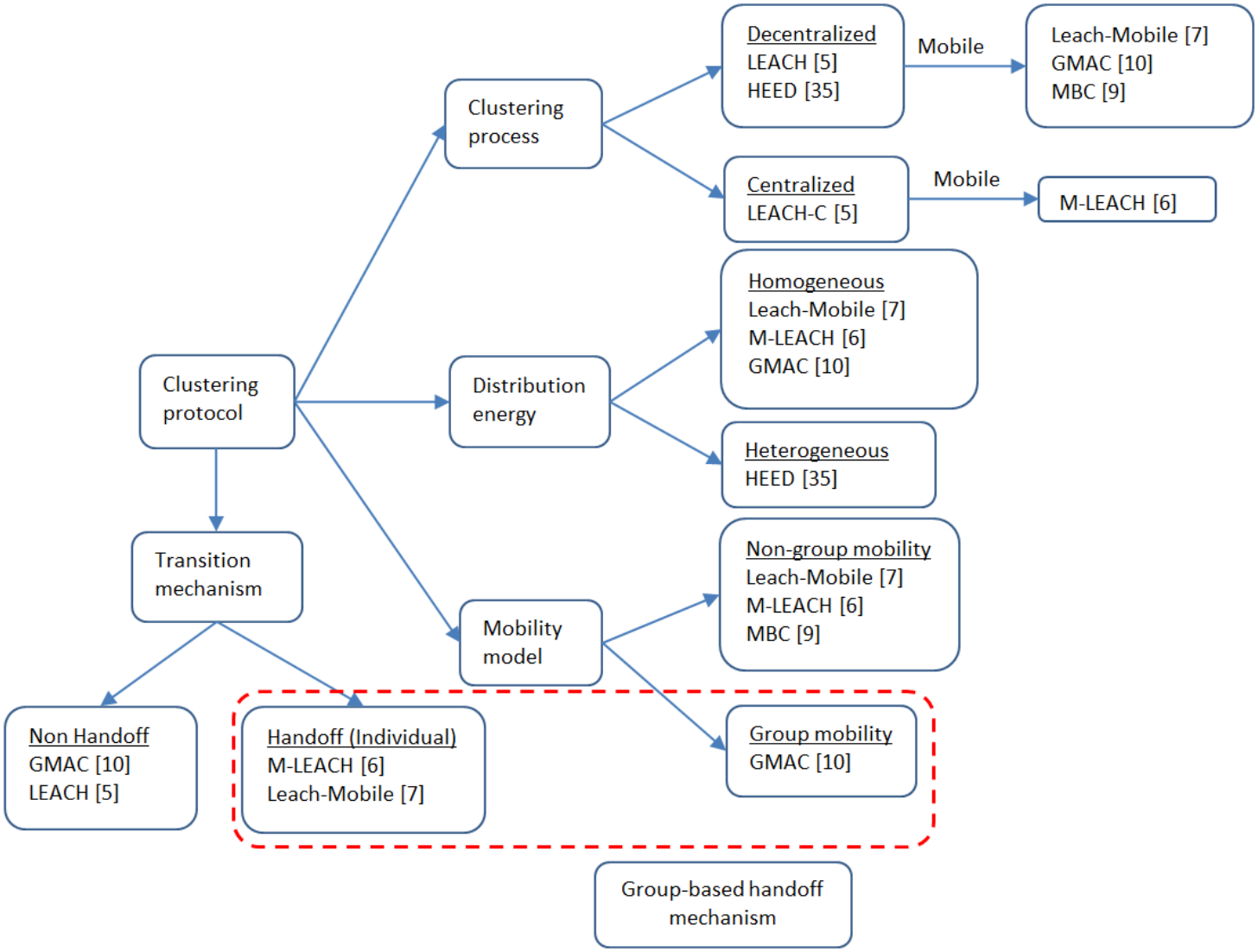
Solution

Adaptive Group Formation Scheme with Clustering for Mobile Group

Issues arise

- **Mobility of the nodes**
- **Group formation and transition**
- **Address frequent topology changes**
- **Reduce control overhead**
- **Reduce energy consumption**
- **Deliver more data to base station**

State-of-the-art Protocol



LEACH Protocol (Clustering)

- **Requirement:**

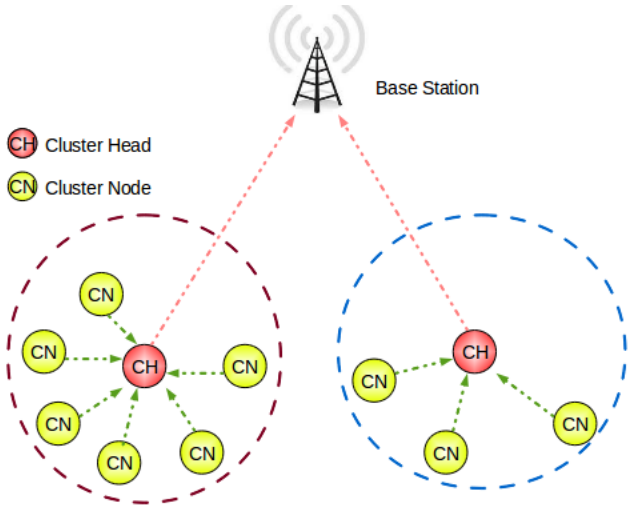
  The system should be able to form clustering to reduce energy consumption.

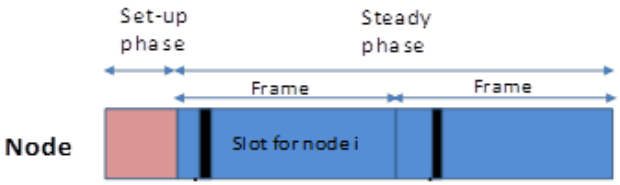
- **State of the art:**

LEACH protocol use de-centralized method to determine cluster.

LEACH-C protocol use centralized method to determine cluster.

Mobile-LEACH supports node mobility.

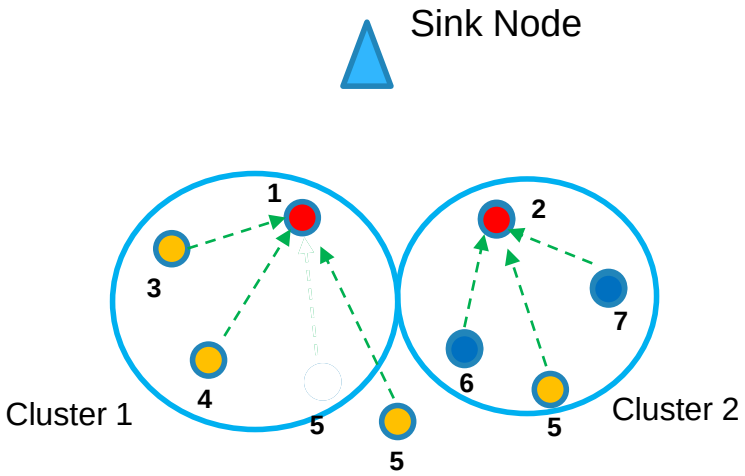




M-LEACH (Mobile LEACH)

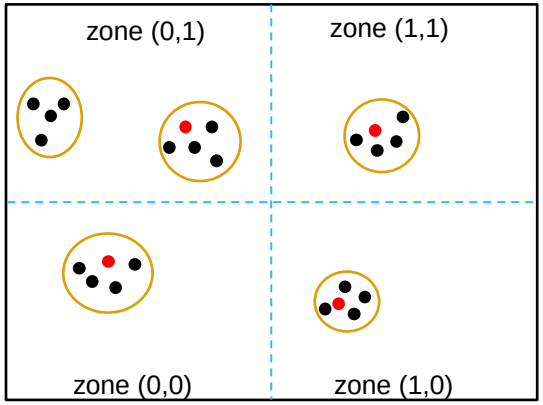
- It uses non-group mobility, individual hand-off mechanism and centralized clustering
- Hand-off mechanism in the clustering protocol
- Definition of Hand-off:

  Hand-off mechanism will occur when the node gets closer to another cluster head to save the energy



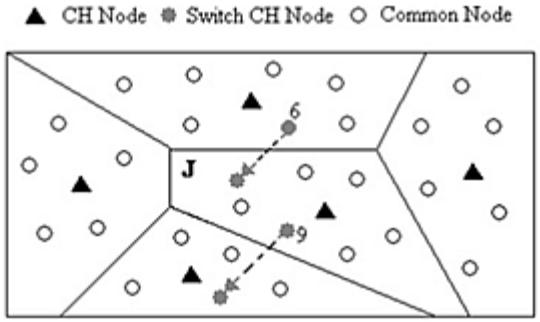
Mobile Clustering Protocol

- GMAC (Group Mobility Adaptive Clustering)
  - ✓ It uses group mobility and zone definition to get steady cluster. However, it does not support hand-off mechanism



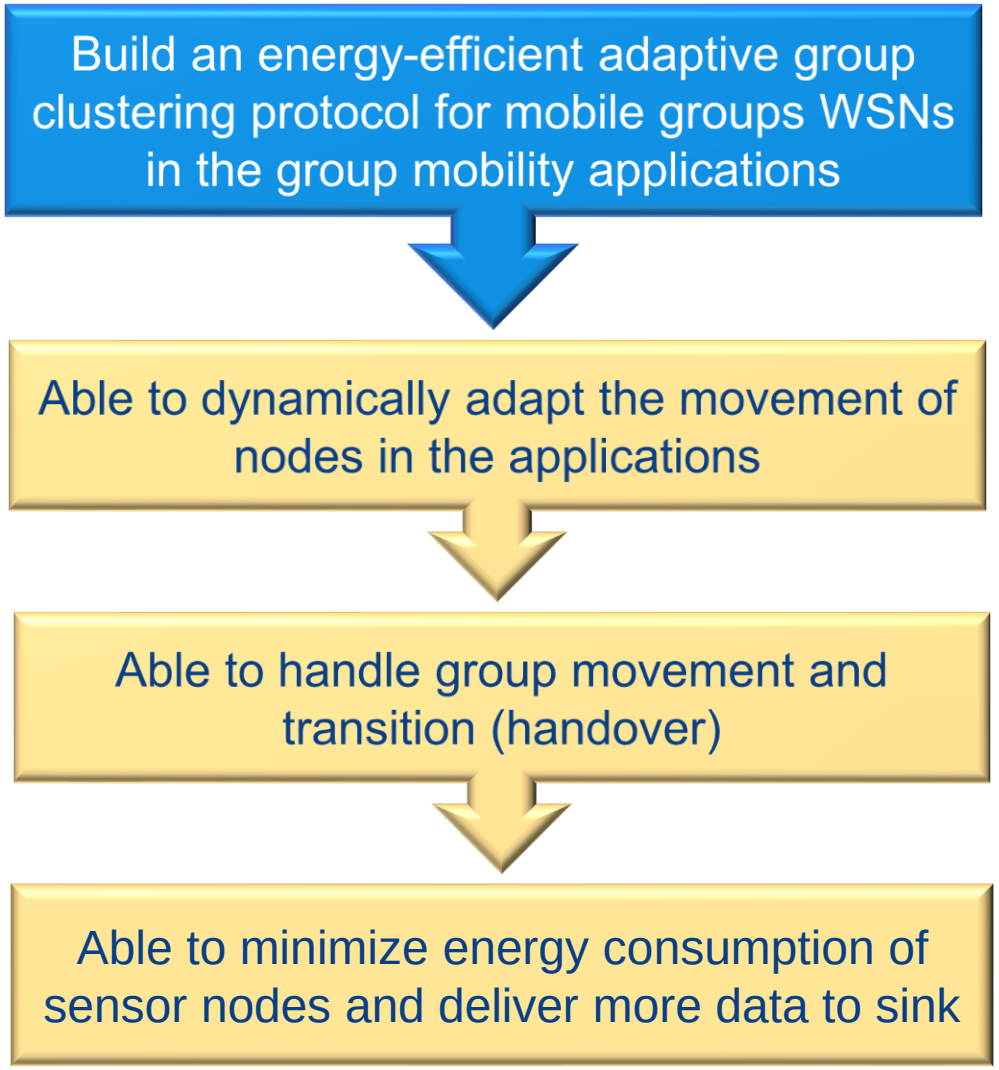
- Cluster-head
- Cluster member

- MBC (Mobility-based Clustering)
  - ✓ Make a stable cluster
  - ✓ Create an adaptive TDMA schedule

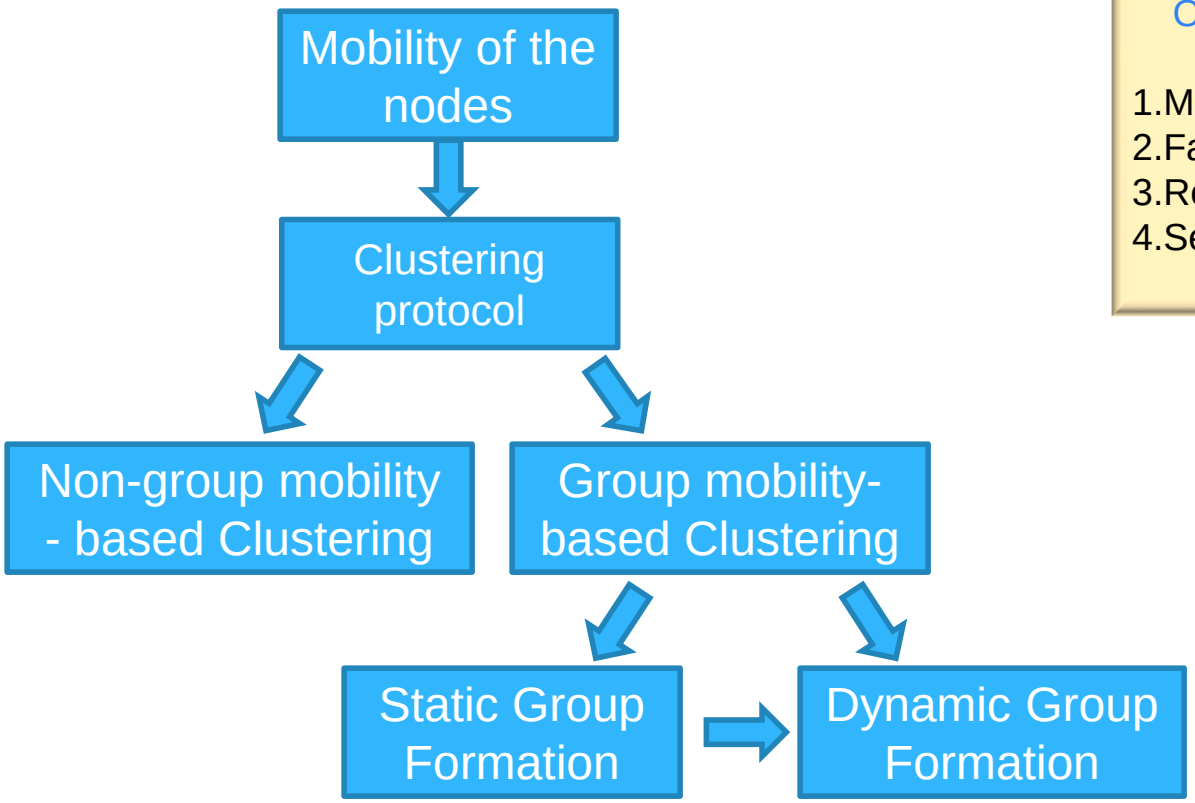


Old TDMA Scheduling	Node 1	Node16	Node 3	Node 9	Node 8	Node 5
New TDMA Scheduling	Node 1	Node16	Node 3	Node 8	Node 6	Node 5

Proposed Protocols: Contributions



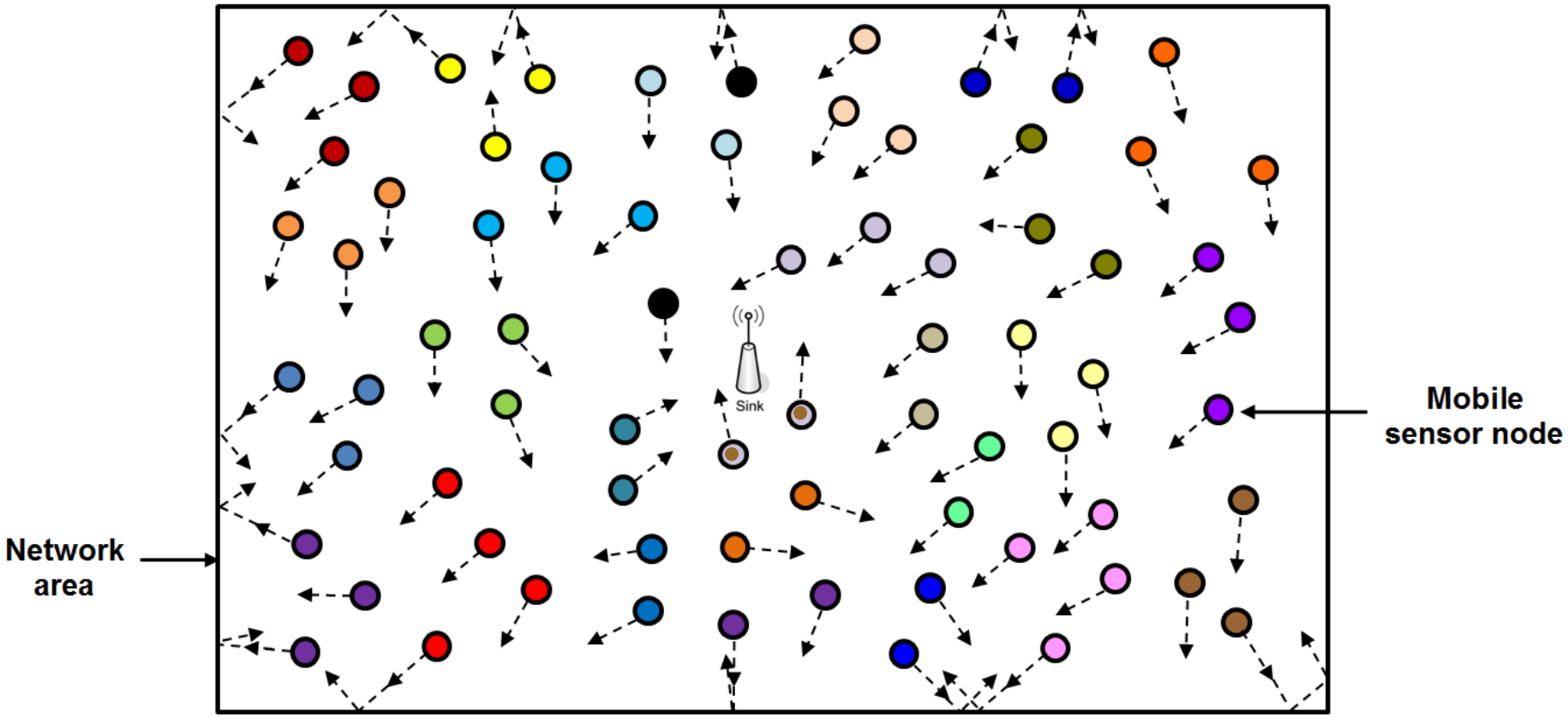
System Framework: Mobility



Objectives of clustering protocol:

1. Maximal network lifetime
2. Fault tolerance
3. Reduce collision (TDMA)
4. Self configuring

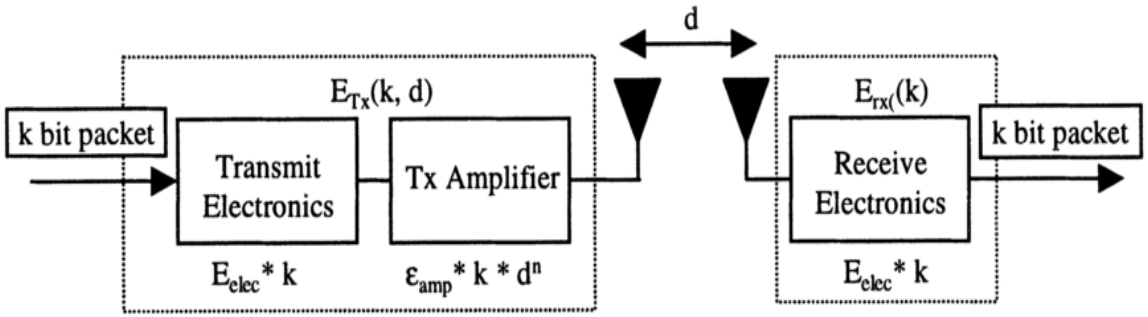
System Models: Network Model



- Sensor nodes move in group into some direction randomly inside network area.
- If the movement of nodes reach the edge of network area, the nodes will turn back their direction into inside the area again.

System Models: Energy Model

Radio energy dissipation model



Transmitter energy

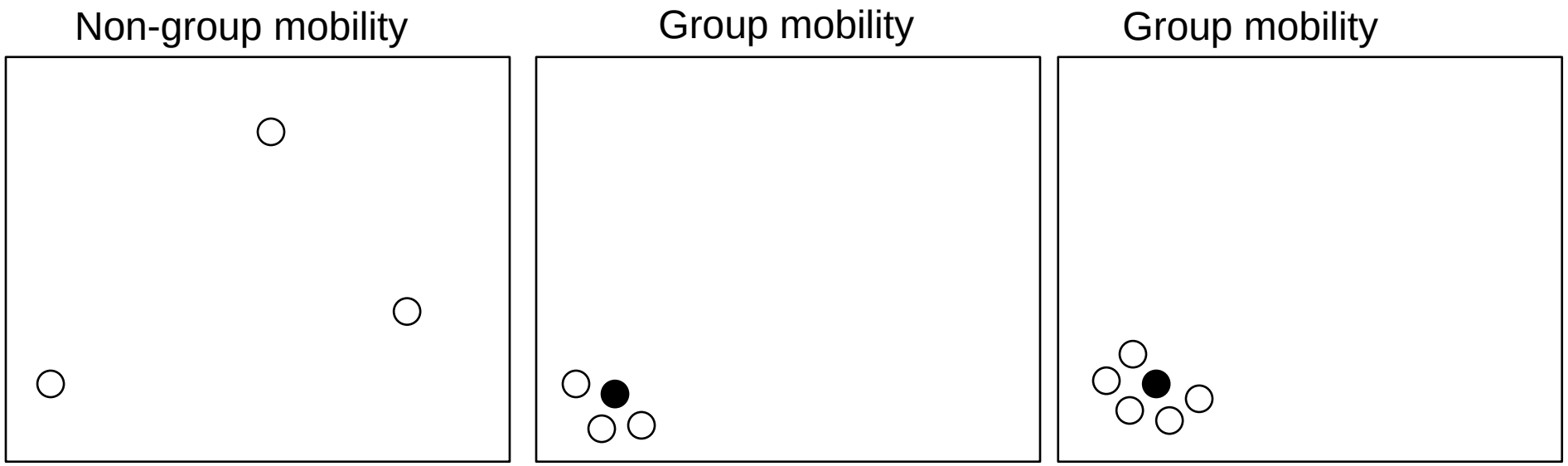
$$E_{TX}(k,d) = E_{Tx-elec}(k) + E_{Tx-amp}(k,d)$$

$$E_{TX}(k,d) = \begin{cases} k.E_{elec} + k.\varepsilon_{fs}.d^2, & d < d_{crossover}\ (Free\ Space) \\ k.E_{elec} + k.\varepsilon_{mp}.d^4, & d \geq d_{crossover}\ (Multipath) \end{cases}$$

Receiver energy

$$E_{RX}(k) = E_{RX-elec}(k) = k\ .E_{elec}$$

System Models: Mobility Model



Random Way Point (RWP)

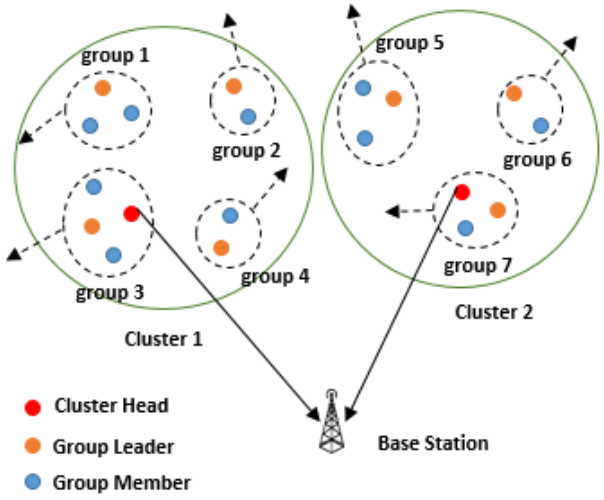
Reference Point Group Mobility (RPGM)

Nomadic Community Mobility (NCM)

- RWP is a random model for the movement of mobile users along a straight line segment from one point to the other.
- In RPGM, each node belongs to a group follows a logical center that determines the flow of the entire group.
- In NCM, some mobile nodes would roam separately from their group around a particular location for a while.

EMGC (Energy-efficient Group Clustering) protocol

Network structure

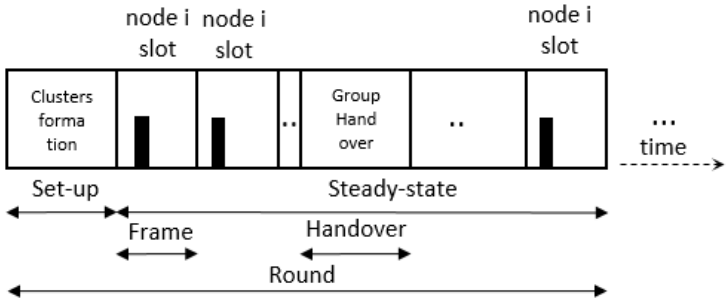


Issues:
Group Movements
Group Handover

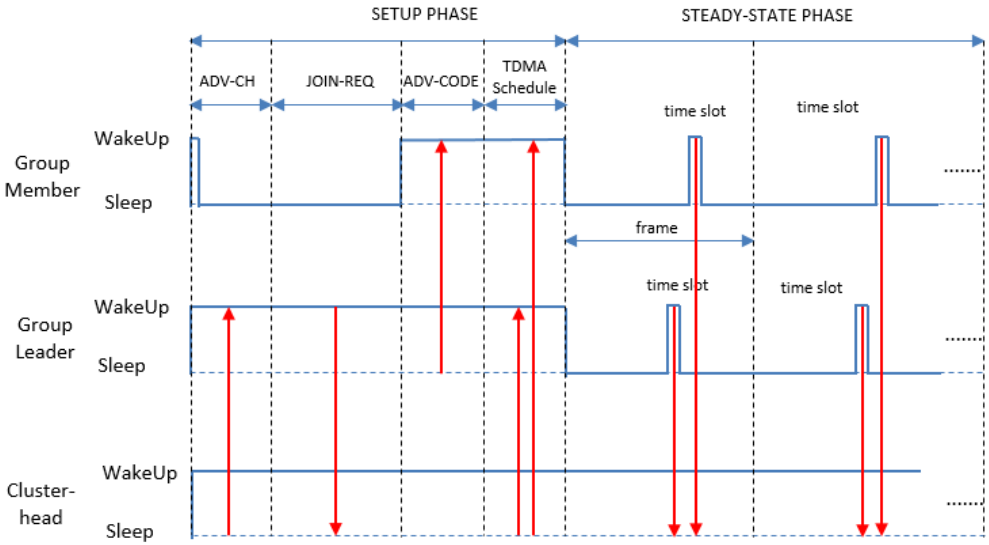
- It consists of three categories of mobile nodes:
  - Cluster Head (CH): major role in cluster formation and to send an aggregated data to BS
  - Group Leader (GL): to make a communication with CH in the set-up and steady-state phase
  - Group Member (GM): as a normal node
- Group formations of all sensor nodes have been determined initially and there is no change in the roles of the group leader and group members.

EMGC protocol: Process

Slot structure



Timing scheme



Threshold to elect CHs

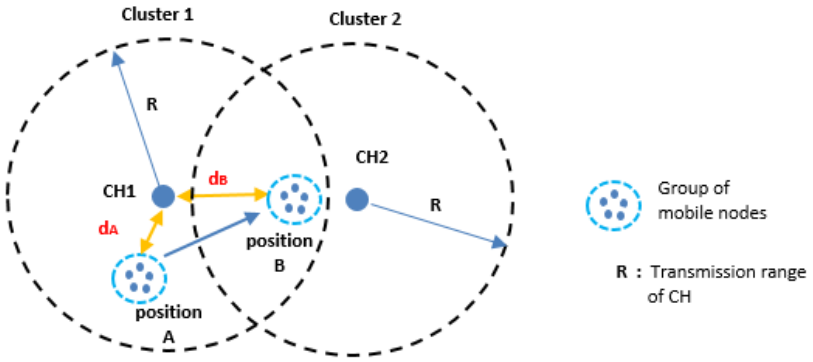
$$T_n(r+1) = \frac{p}{1 - p.(r \bmod \frac{1}{p})} \cdot \left(\frac{E_n(r+1)}{E_{max}} \cdot \frac{v_{max} - v_n(r+1)}{v_{max}} \right)$$

% of CHs — energy — speed

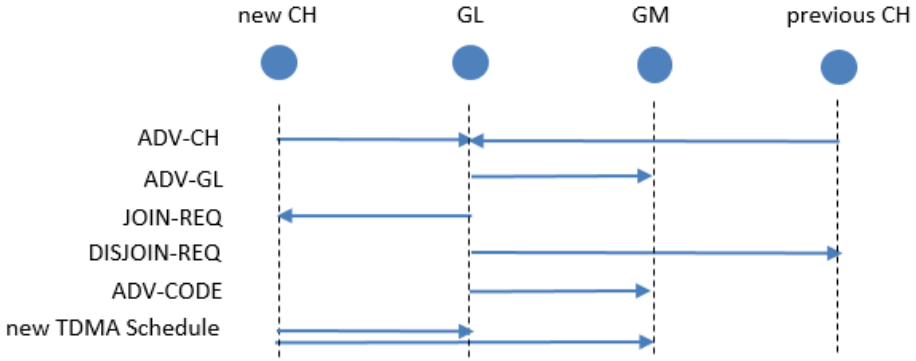
- There are two phases:
  - Set-up phase: cluster formation with three category nodes
  - Steady-state phase: data delivery to a BS with group handover

EMGC Protocol: Group Handover

Group handover process



Group handover procedure



- A two-step decision to decide group handover:
  1. Calculate a willingness $(F_j(r))$ to join the new cluster

$$F_j(r) = d_j(t_{hr}) - d_j(t_{sr})$$

Distance GLj to CH1 at pos. A — **Distance GLj to CH1 at pos. B**

  2. If *F* is positive (the group moves away), it will choose the best cluster.

$$H_j(r) = \arg\min_k d_j(t_{hr})$$

Distance GL_j and CH_k at round *r*

Simulation Parameters

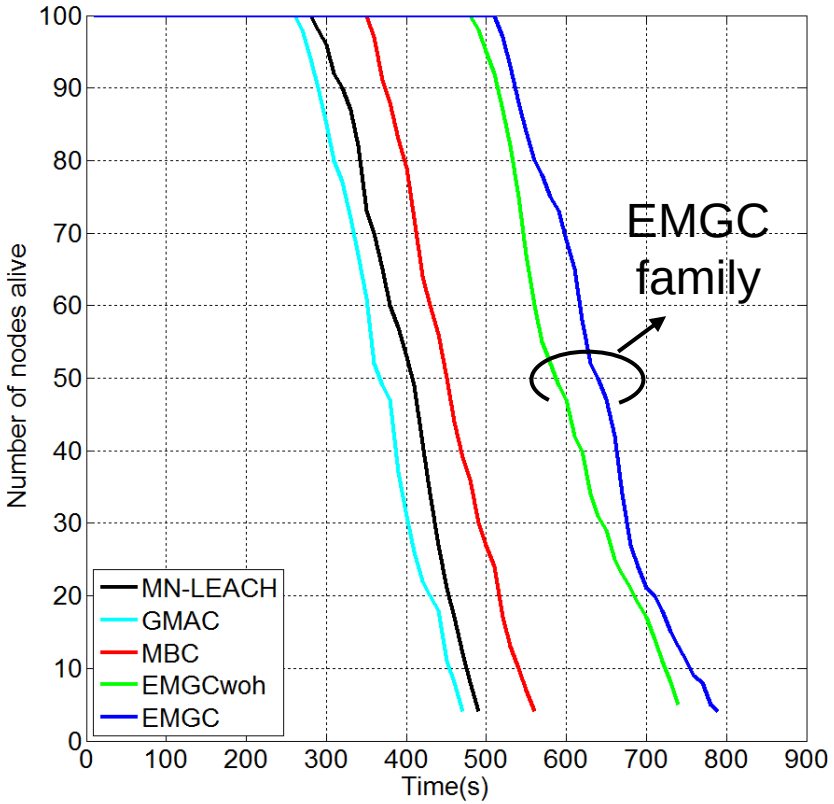
- The simulation is done in network simulator 2 (NS2)
- The simulation environment is as below:

Parameters	Values
Network size	100x100 m^2
Size of packet	500 bytes
E_{init} (Initial Energy)	2 J
Number of nodes	100
Percentage of groups (P_g)	5%, 10%, 20%, 30%
Max. distance to the group center	8 m
Max velocity of mobile nodes	2 m/s, 5 m/s, 10 m/s
Location of BS	the center of networks

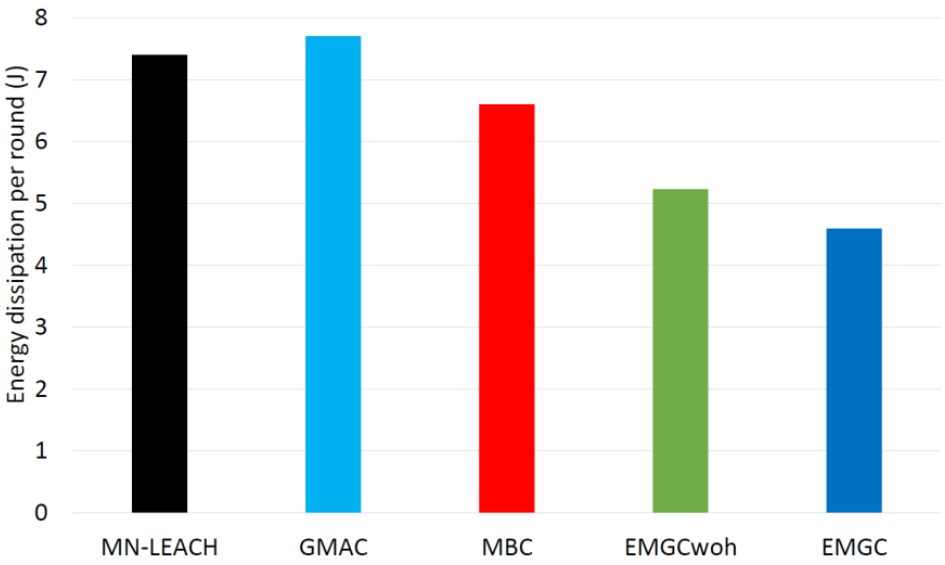
- There are two schemes of EMGC:
  - EMGC: with group handover mechanism
  - EGMCwoh: without group handover mechanism

Simulation Results: Fixed Percentage of Groups (1/3)

Network Lifetime



Energy dissipation



- Set P_g 10%, max speed 2 m/s
- EMGC outperforms the other protocols because it has categorized nodes and group handover. Therefore, it reduces energy dissipation per round.

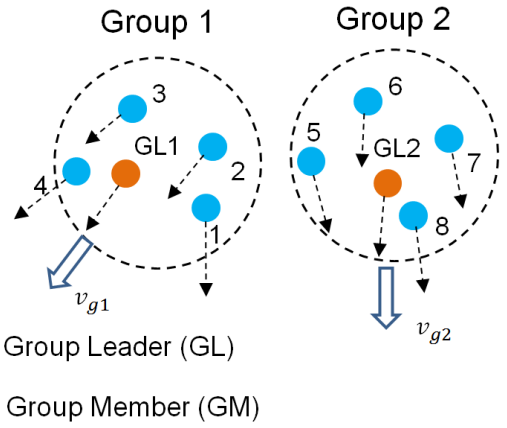
Proposed Protocols: Objectives

- To address a dynamic group change in clustering scheme.
- To address high percentage number of groups problem.
- To reduce the number of control packets and collisions.
- To prolong lifetime of the network.
- To deliver more data to a BS.

To address the above problems, we propose:

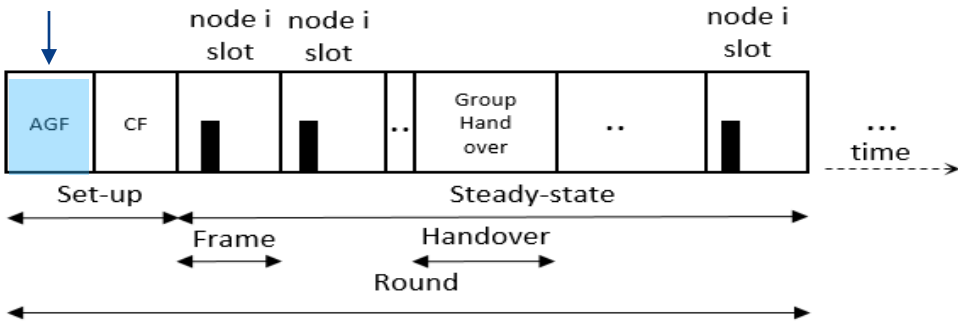
Adaptive Group Formation with EMGC (AgEMGC) for mobile group WSNs

AgEMGC Protocol: Basic Function

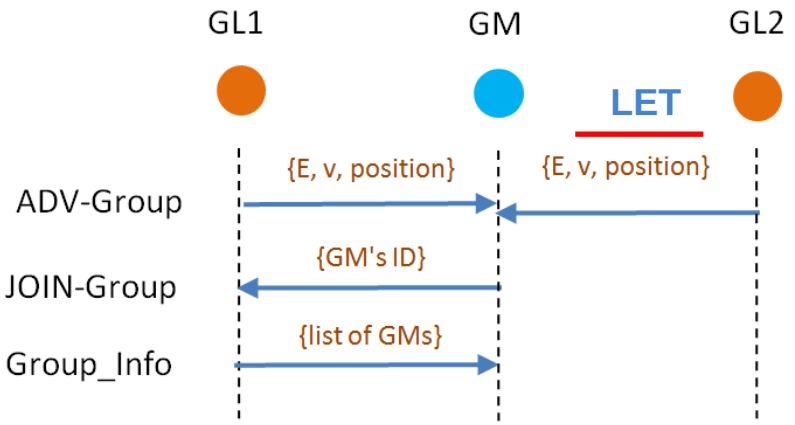


Adaptive Group Formation

Slot structure



Basic function



- There are 2 basic functions:
  - A dynamic group change
  - Group merging
- There are two additional functions:
  - GL rotation: to reduce the energy consumption
  - A stay Connection procedure: to reduce the control packet

Metric to choice the best GL:

$$G_{ij}(r) = \delta \cdot \frac{LET_{ij}(r)}{T_r} + \rho \cdot \frac{E_j(r)}{E_{init}}$$

$\delta = 0.4$

$\rho = 0.6$

GL's energy

AgEMGC Protocol: variant of protocols

- There are 4 proposed schemes:
  - AgEMGC : as a basic function of Adaptive Group Formation.
  - AgEMGCwg: with GL rotation.
  - AgEMGCwc : with a stay Connection procedure.
  - AgEMGCwgc : with GL rotation and a stay Connection procedure.

THANK YOU