

Wireless Sensor Networks

5. Routing

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- MANET Routing
 - Flooding Based Routing (MANET)
 - Flooding, DSR, AODV, DYMO
 - Cluster-Based Hierarchical Routing
 - Low-Energy Adaptive Clustering Hierarchy (LEACH)
- Geographic Routing
 - Greedy Routing
 - Face Routing
- Self-Organizing Coordinate Systems
 - Inferring Location from Anchor Nodes, Virtual Coordinates
 - Gradient Routing
 - Gradient-Based Routing (GBR)
 - Routing Protocol for Low Power and Lossy Networks (RPL)

Low-energy adaptive clustering hierarchy (LEACH)

$$\begin{array}{l}
 A \quad (+1 \quad -1 \quad +1 \quad -1) \quad 0 \\
 B \quad (+1 \quad +1 \quad -1 \quad -1)
 \end{array}$$

Literature

- Heinzelman, W., Chandrakasan, A., and Balakrishnan, H., "Energy-Efficient Communication Protocols for Wireless Microsensor Networks", Proceedings of the 33rd Hawaain International Conference on Systems Science (HICSS), January 2000.
- Heinzelman, Chandrakasan, Balakrishnan, An Application-Specific Protocol Architecture for Wireless Microsensor Networks, IEEE Transactions on Wireless Communications, Vol. 1, NO. 4, October 2002

TDMA-based MAC + simple Routing Protocol

Cluster heads (CH)

- Randomized, adaptive, self-configuring algorithm
- use CDMA for communication

Other nodes

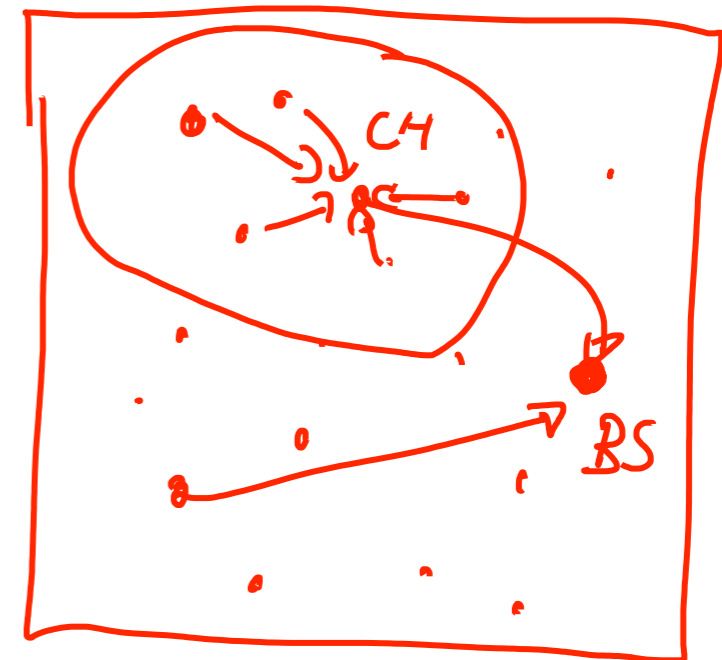
- communicate only with cluster head using TDMA-MAC

Application specific data processing

- aggregation, compression

Two-hop-Routing

- Nodes to CH, CH to base station
- Minimum energy routing



TDMA

Code



Adaptive versus Static Clustering

- Cluster members transmit to a cluster head
- Cluster head
 - transmits to the sink
 - Cluster heads are energy intensive
 - are the first to die
- LEACH
 - nodes self-elect to become cluster heads
 - Cluster-heads data from their surrounding nodes and pass it on to the base station
 - is dynamic because the job of cluster-head rotates

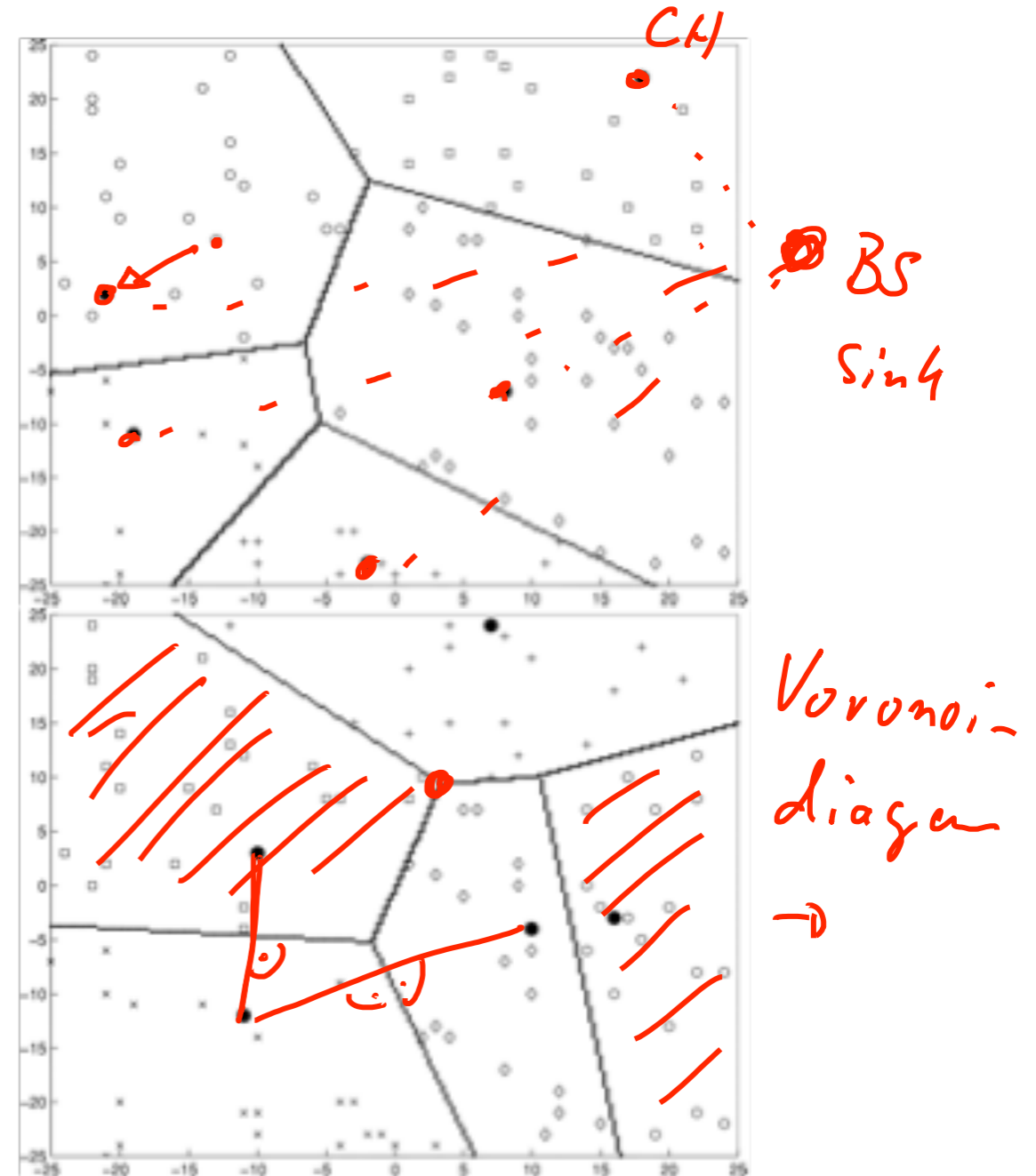
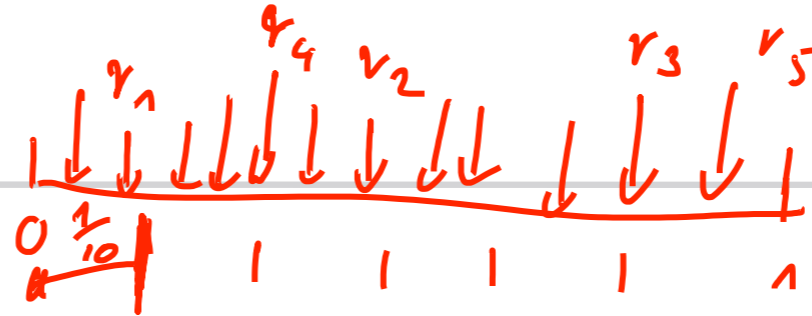


Fig. 3. Dynamic cluster formation during two different rounds of LEACH. All nodes marked with a given symbol belong to the same cluster, and the cluster head nodes are marked with •.

- Steps
 - Cluster Head Selection
 - probabilistic or
 - central (LEACH-C) by base station
 - Cluster Formation
 - Steady State Phase
- Assumptions
 - All nodes can reach the base station (BS)
 - Short transmission ranges can save energy
 - energy path loss $\sim d^2$

LEACH: Cluster Head Selection Algorithm



- Given
 - k: number of desired cluster heads
 - n: number of nodes
 - $p = k/n$ desired fraction of nodes
 - such that $1/p$ is a natural number
 - t: round number
 - $t_0 = t - (t \bmod 1/p)$

$$p = \frac{10}{100} = 0.1 \quad \frac{1}{p} = 10$$

$$p \cdot n = \frac{k}{n} \cdot n = k \quad 0.1 \cdot 100 = 10$$

- Choose randomly $r \in [0, 1]$

- In each round compute $T(t)$:
$$T(t) = \frac{p}{1 - p(t \bmod \lceil \frac{1}{p} \rceil)}$$

$$T(t) = \frac{p}{1 - 0} = p$$

- probability that a node i elects itself to become a cluster head

- If $(r < T(t))$ and (node has not been a cluster head in the last $1/p$ rounds) then

$$t = \frac{1}{p} - 1$$

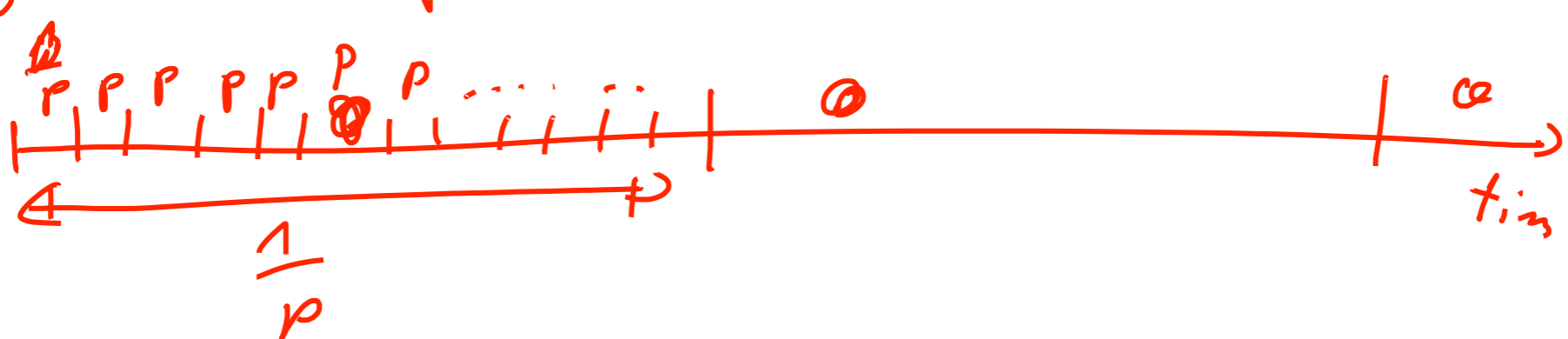
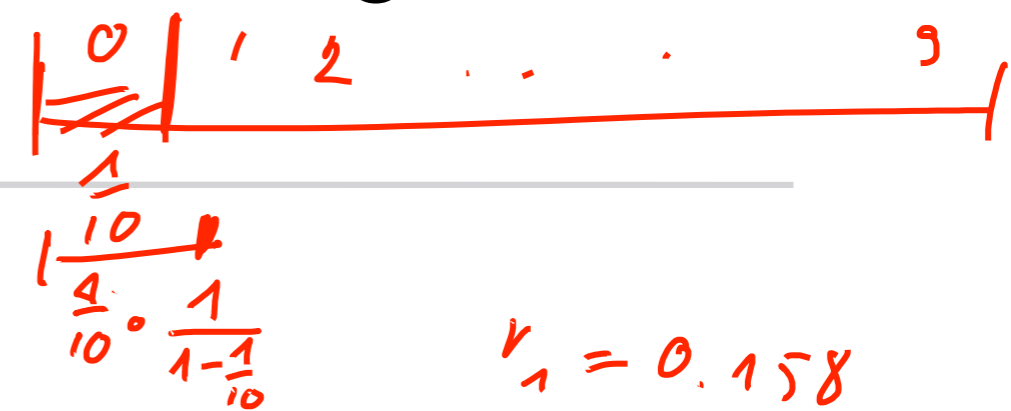
- Select node as cluster head for round r

$$\frac{p}{1 - \frac{p}{p} + p} = \frac{p}{p} = 1$$

LEACH: Cluster Head Selection Algorithm

Exp. selected CH

t	$n \cdot p$	Probability = threshold	
$t=0$	$= 4$	p	$v_1 = 0.158$
$t=1$		$\frac{p}{1-p}$	$v_2 = 0.378$
$t=2$		$\frac{p}{1-2p}$	
\vdots			
$t = \frac{1}{p} - 1$		1	



LEACH: Cluster Formation Algorithm

- Cluster Heads broadcasts an advertisement message using CSMA
- Based on RSSI (received signal strength indicator)
 - each non-cluster node determine its cluster head for this round
- Each non-cluster head transmits a join-request message
 - using CSMA
- Cluster head node sets up a TDMA schedule for data transmission within the cluster
 - prevents collision
 - energy conservation for non-cluster-heads

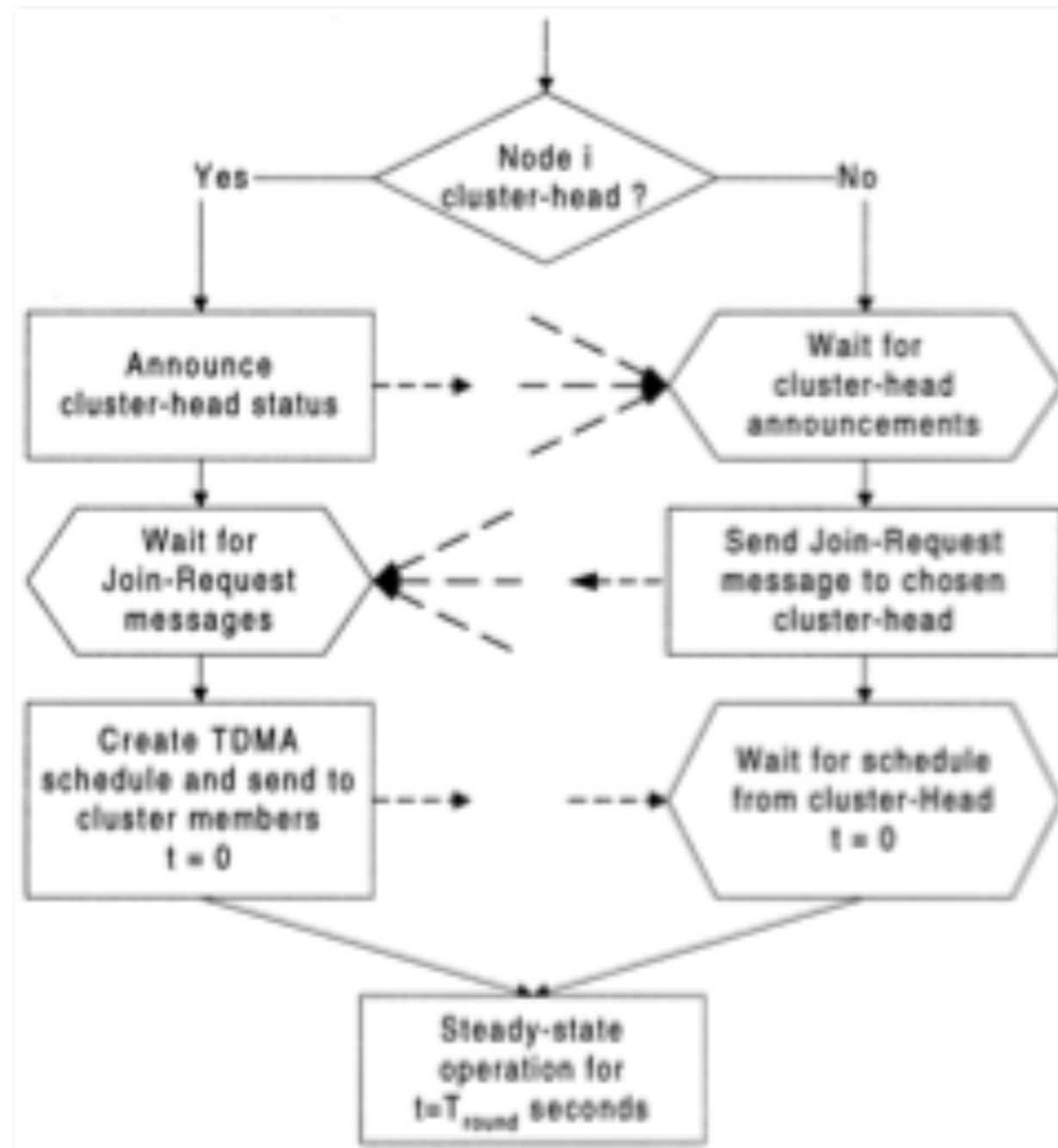
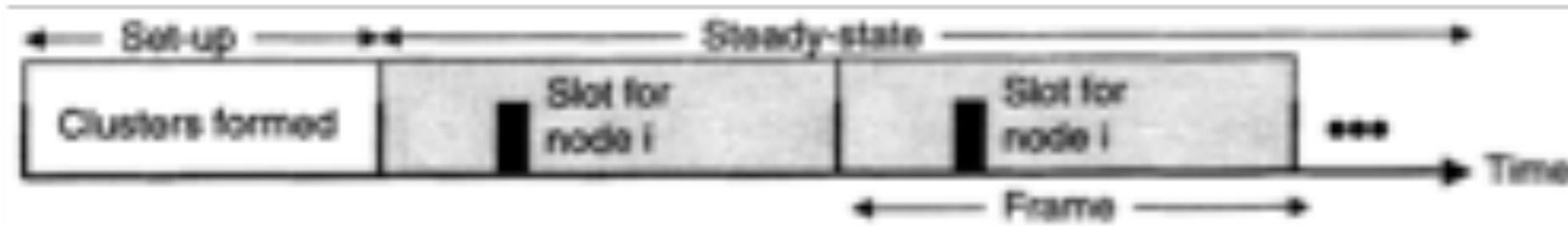


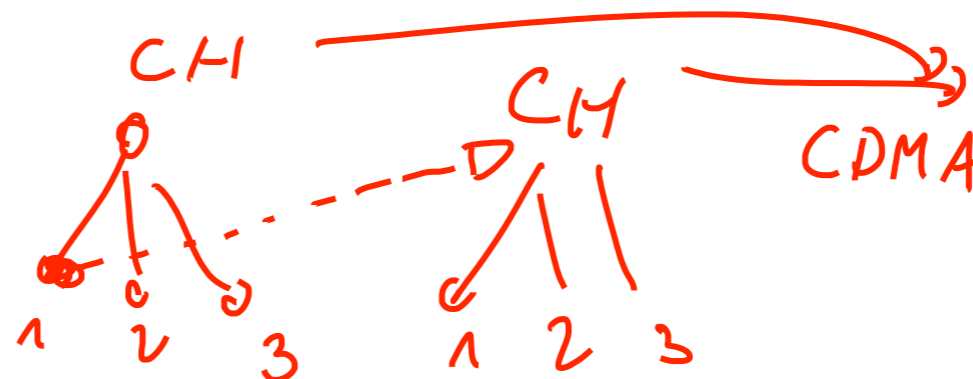
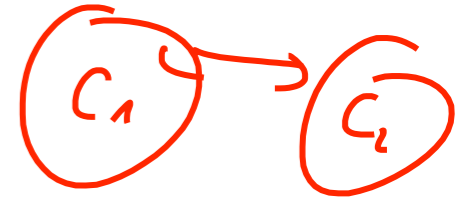
Fig. 2. Flowchart of the distributed cluster formation algorithm for LEACH.

LEACH: Steady State Phase



Assumptions

- Setup phase starts at the same time
- BS sends out synchronized pulses to the nodes
- Cluster heads are awake all the time
- To reduce inter-cluster interference, each cluster communicates using direct-sequence spread spectrum
- Data is sent from the cluster head to the base station using CDMA



LEACH: Optimal number of clusters

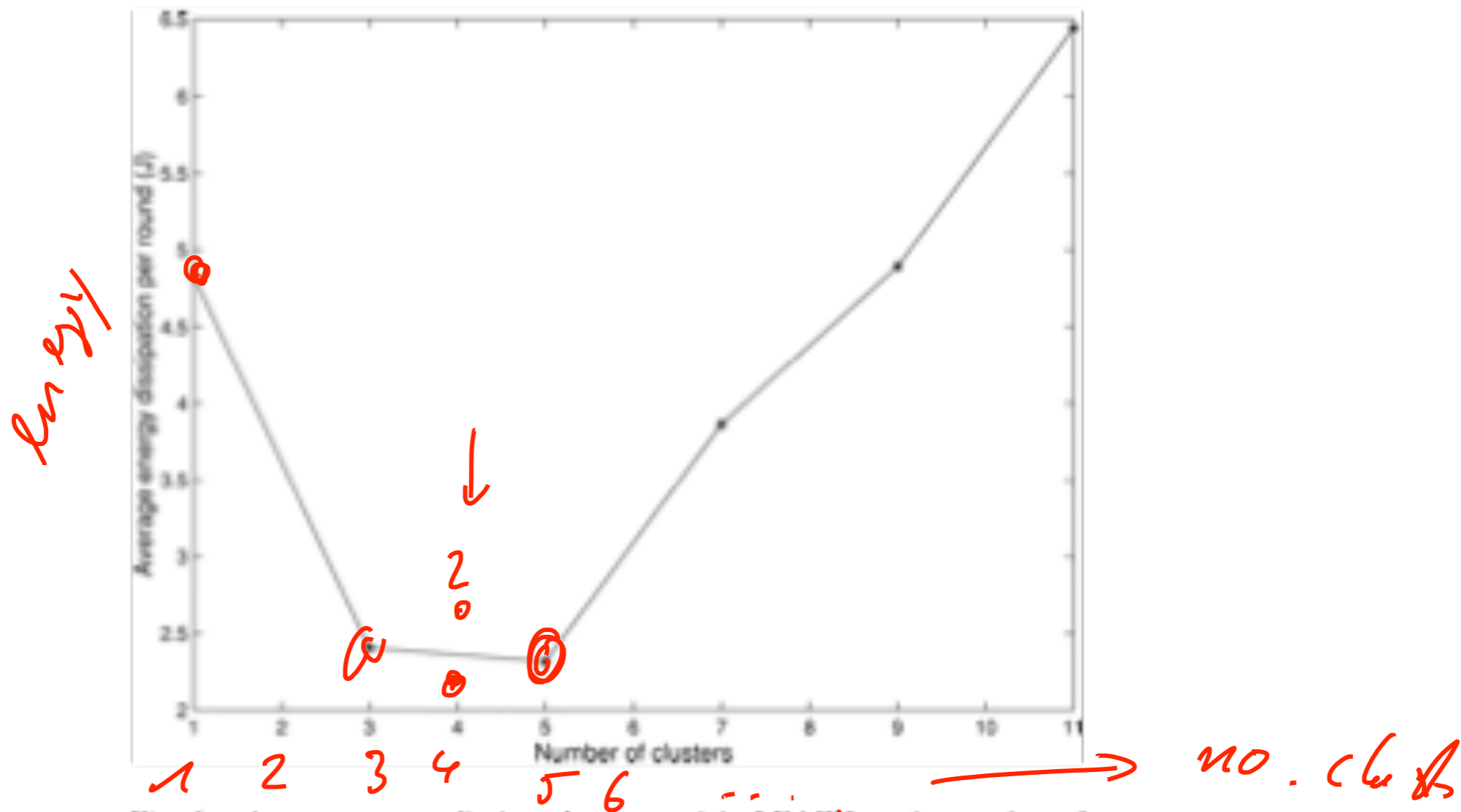


Fig. 6. Average energy dissipated per round in LEACH as the number of clusters is varied between 1 and 11. This graph shows that LEACH is most energy efficient when there are between 3 and 5 clusters in the 100-node network, as predicted by the analysis.

- Base station cluster formation
- Use a central control algorithm to form clusters
 - During setup phase each node sends its location and energy level to the base station
 - base station assigns cluster heads and cluster
 - base station broadcasts this information
 - steady-state phase is same as LEACH



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Algorithms for Radio Networks

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