An Implicit Prioritized Access Protocol for Wireless Sensor Networks

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Outline

- Challenges and goal
- Network architecture (cellular structure)
- Medium Access Control (MAC)
  - Implicit EDF
  - Intra-cell & inter-cell communication
- Frame reclaiming technique (FRASH)
- Experimental results
- Conclusions

Wireless sensor networks

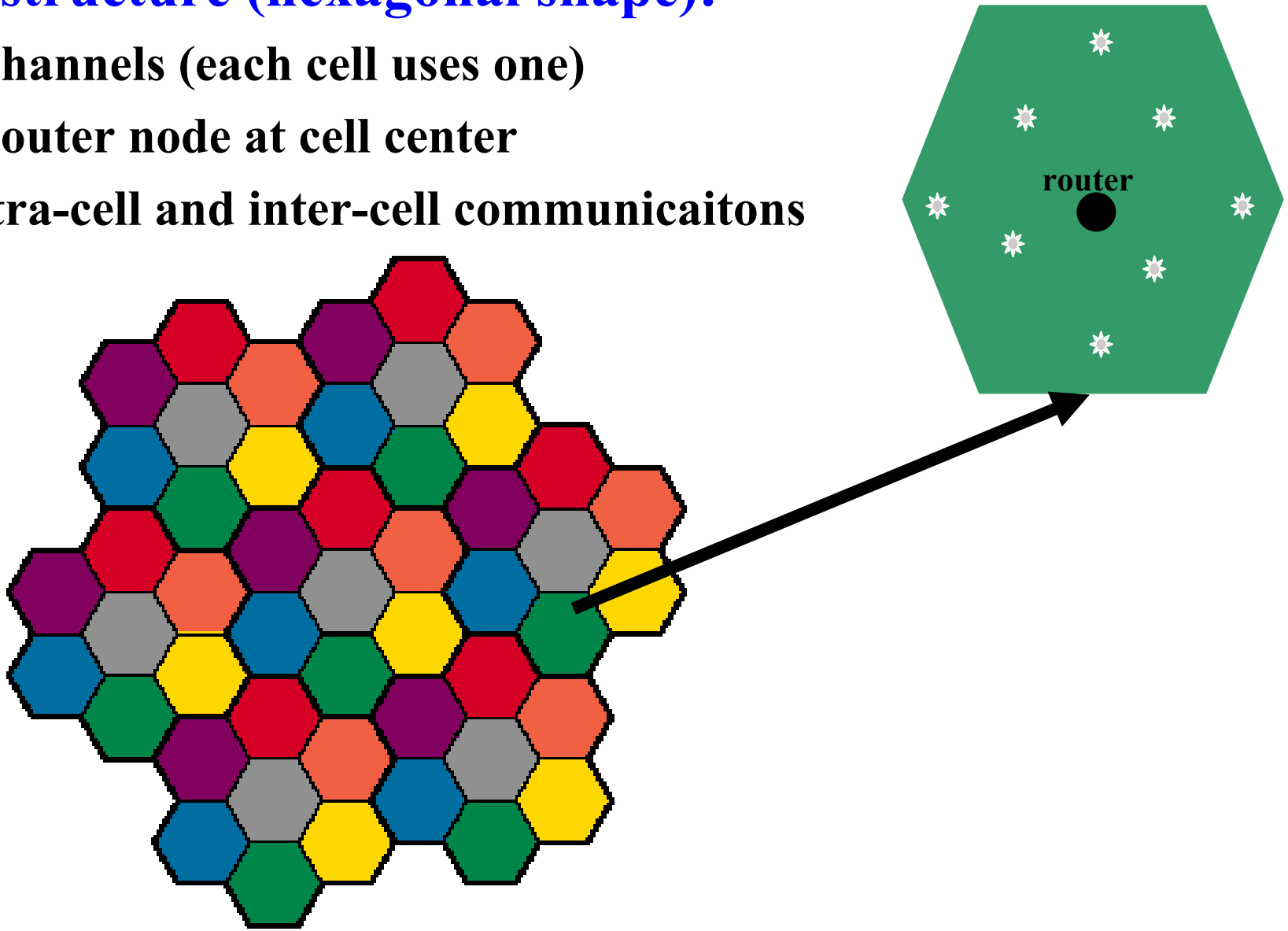
- Sensor networks differ from classical ad hoc networks in three fundamental aspects:
  - —messages are mainly periodic and need guaranteed bounded delay;
  - —sensors can gather the same information creating a lot of redundant data;
  - —nodes are typically fixed, while the tracked targets move inside the network.

- Assumptions:
  - —nodes are statically located
  - —Nodes are synchronized on a frame base

Network architecture

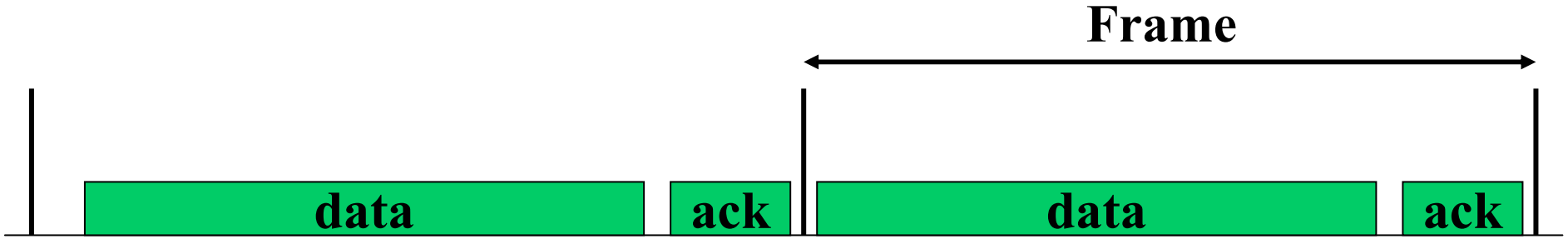
Cell structure (hexagonal shape):

- 7 channels (each cell uses one)
- a router node at cell center
- Intra-cell and inter-cell communicaitons



Intra-cell communication

- Medium Access for intra-cell communication
- Time is divided into synchronized frames



- Inside each cell, messages are scheduled by EDF on frames:
  - ➔Periodic nature of sensor data streams, once initialized, allows for EDF scheduling via implicit contention
  - ➔no contention phase, no conflicts, no backoff

Implicit prioritized medium access using EDF

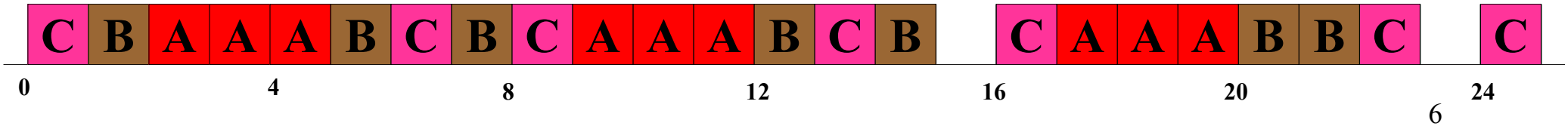
- Distributed scheduling
- The EDF scheduler is replicated to each cell node

node	*message size (frames)*	*period (frames)*
A	3	8
B	1	6
	1	8
C	1	4

This table is stored in each node of one cell

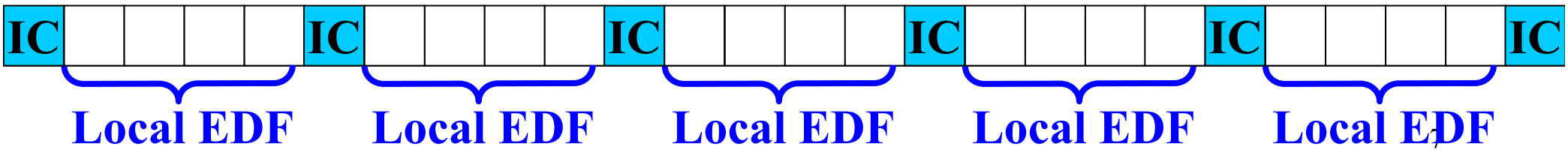
$$\sum_i \frac{MsgSize_i}{period_i} = \frac{3}{8} + \frac{1}{6} + \frac{1}{8} + \frac{1}{4} \leq 1$$

Message set is schedulable!

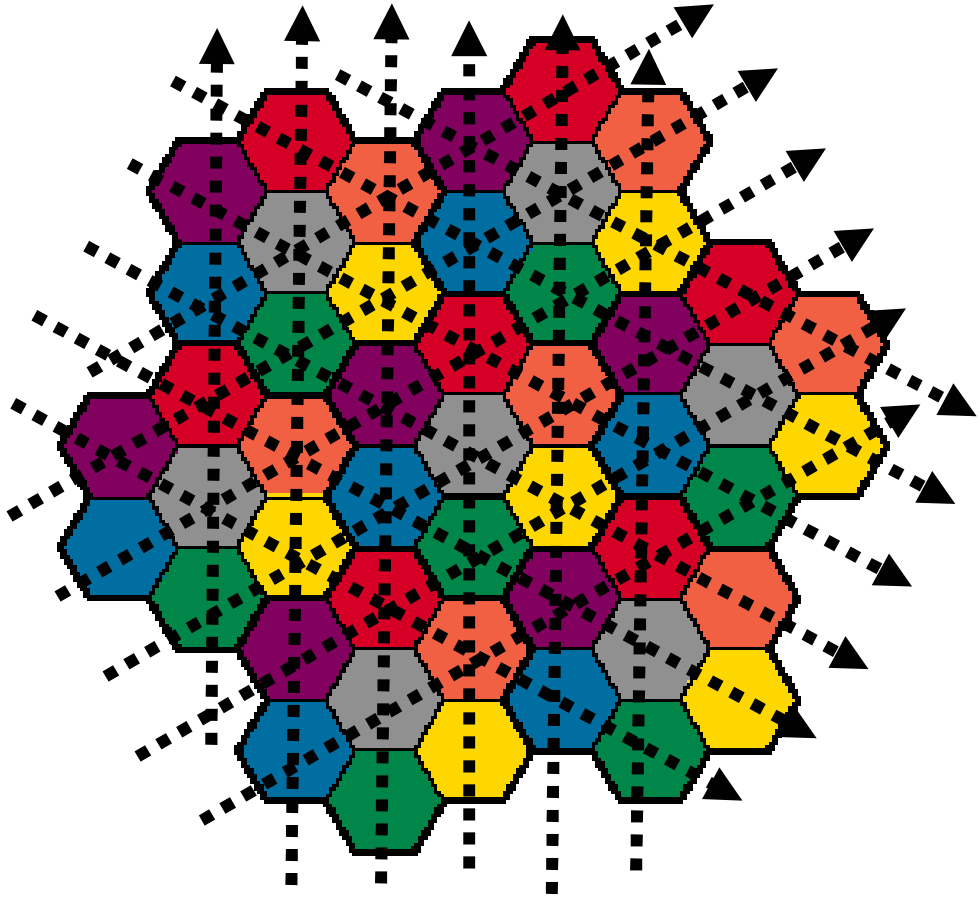


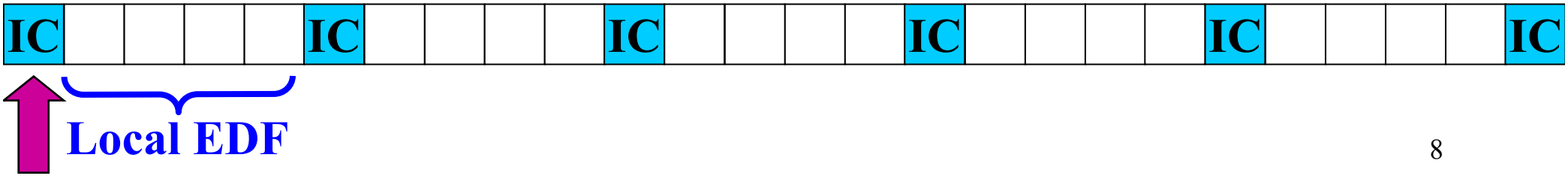
Inter-cell communication

- Inter-cell communication mechanism uses TDM+EDF
  - Routers have two transceivers
    - Used at the same time on different channels
  - Sender uses its own cell frequency
  - Receiver uses the channel of the cell from which it expects
  - Each router sends the message with earliest deadline
  - Inter-cell frames are reserved



Inter-cell communication



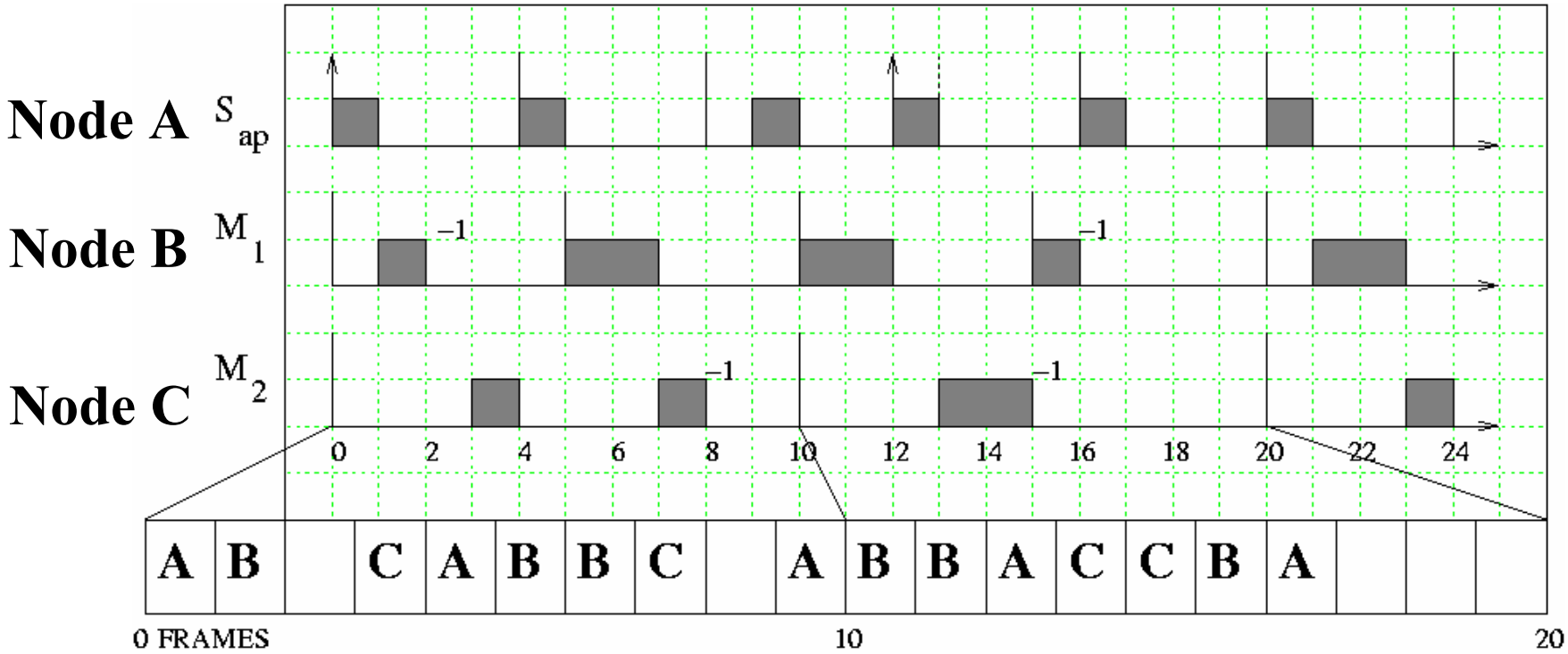


Problems with implicit EDF

- **Implicit EDF drawback** ➔ if a message finishes earlier, the unused reserved frames are wasted
- Implicit EDF cannot reclaim unused reserved frames!

An example

A	1(4)	4(16)
B	2	5
C	3	10



A resource reclaiming mechanism (FRASH)

- FRASH reclaims the reserved frames which are left unused by the hard messages:

  ➔If a message does not use all the reserved frames, its early completion is notified to the other nodes (indicate in the header of the last data packet of the current message).

  ➔All cell nodes detect it.

  ➔The next eligible node, if any, can exploit the spare frames or propagate them to the next one (how?).

FRASH rules

- **FRASH rules:**

  - **Message early completion:**

    ➔the spare frames are marked as FREE in local ready queue and are notified to the other nodes;

  - **Spare frames freed by a neighbor:**

    ➔ if a node receives the notification of spare frames, it marks them as FREE in the local ready queue;

  - **Messages are ordered by each node according to EDF:**

    ➔ The earliest deadline message is transmitted only by its sender node;

FRASH rules

- **Free frames keep the deadline of the message they belonged to:**

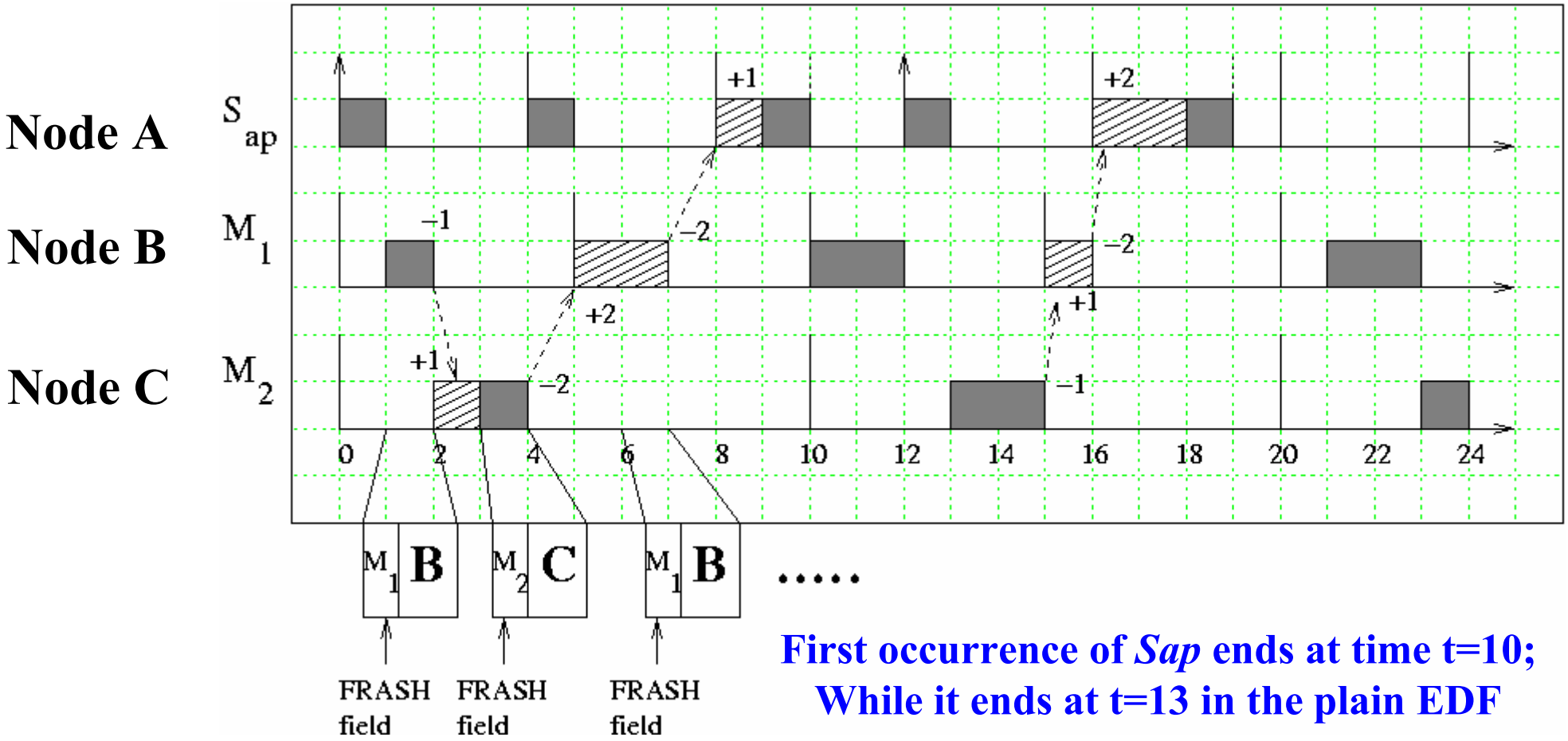
  ➔ When a free frame has the earliest deadline, the following message, if any, can inherit its deadline and capacity;

- **One or more ready queue contains only free frames:**

  ➔ the free frames are treated as the same as reserved frames but leaving the wireless channel idle.

Example

- Example of frame reclaiming using FRASH

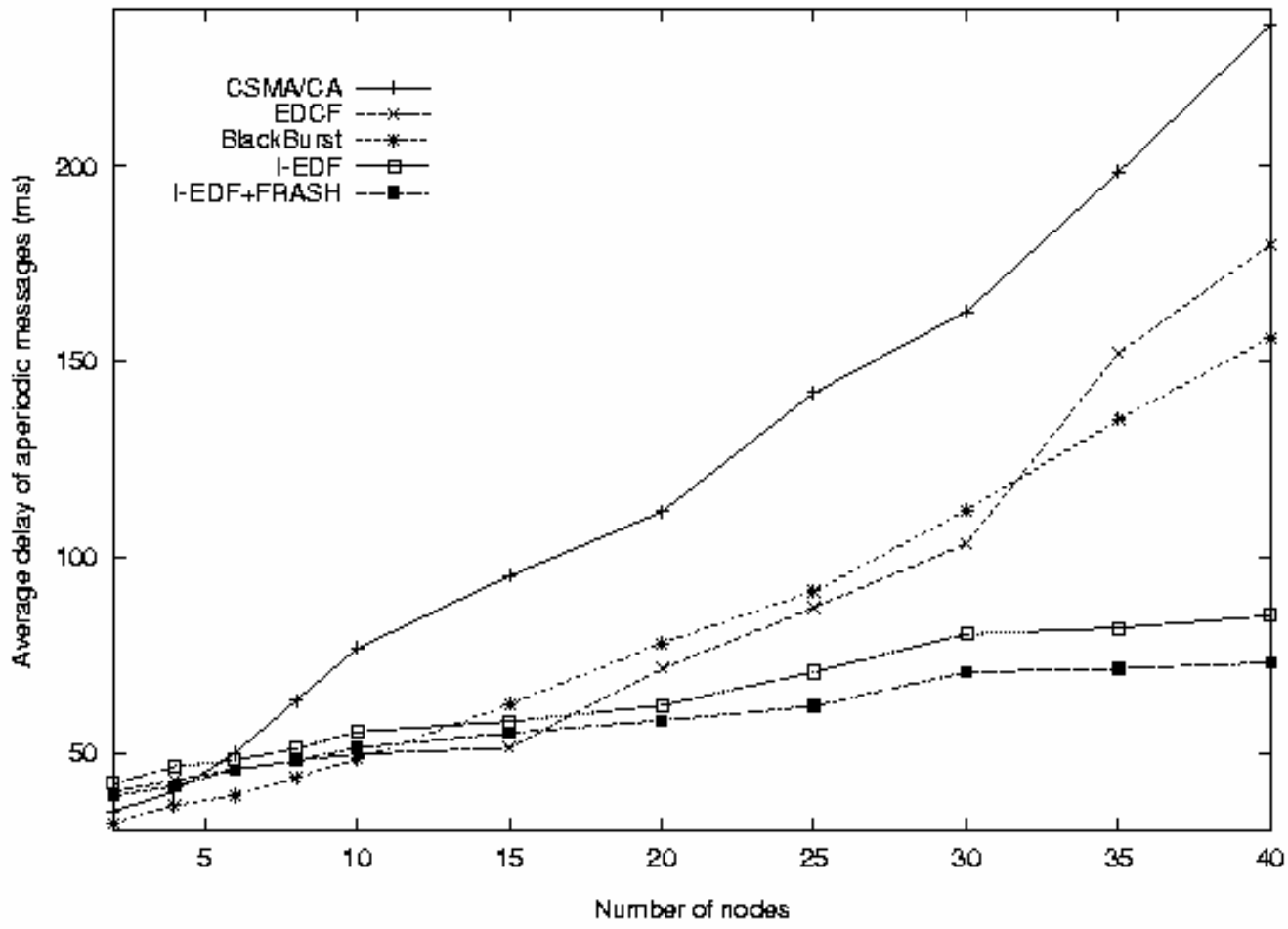


First occurrence of *Sap* ends at time t=10;
While it ends at t=13 in the plain EDF

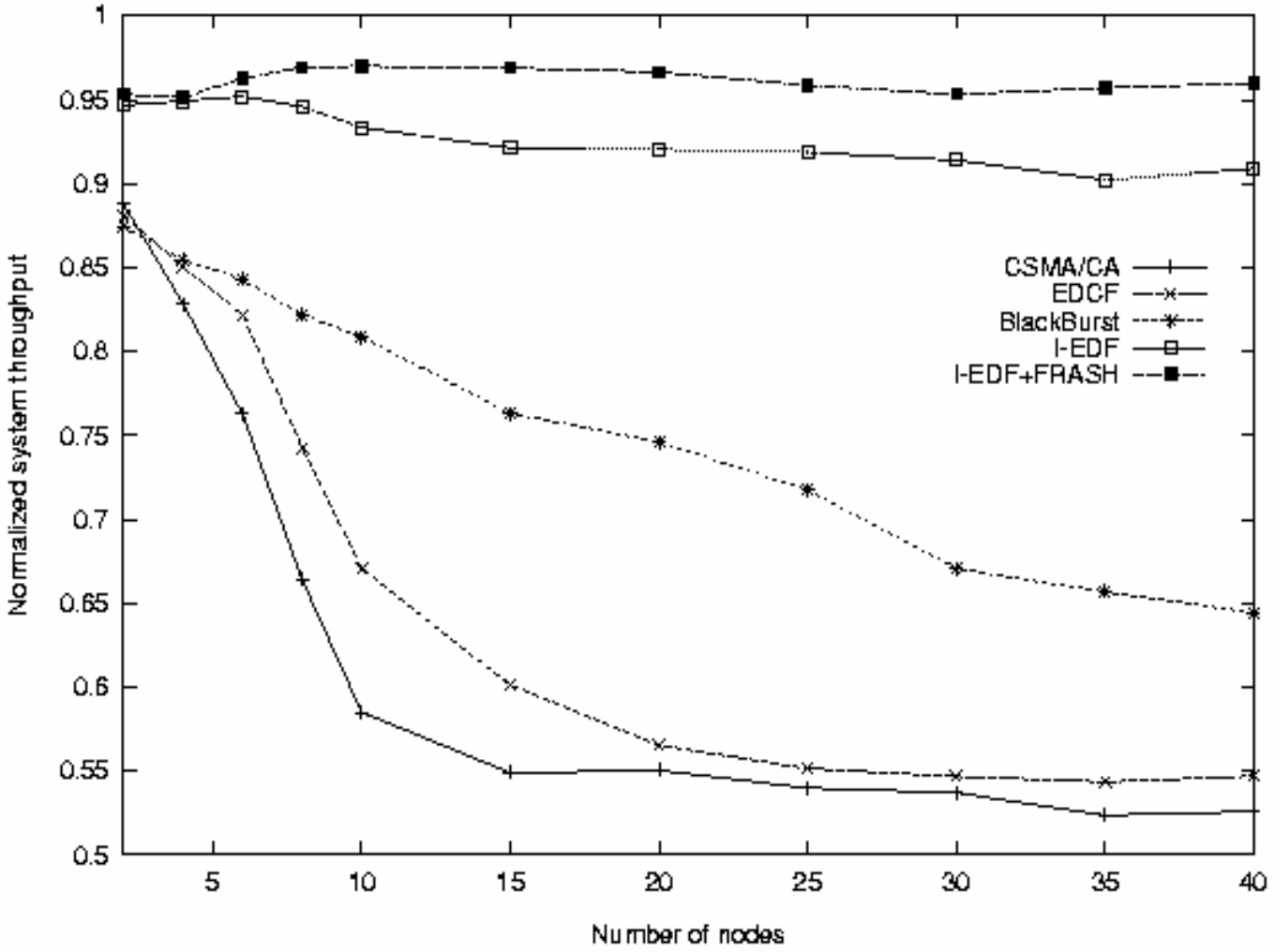
Experimental results

- A set of experiments was run in the ns-2 network simulator
- Schemes have been compared with Black-Burst, Enhanced DCF and CSMA/CA.
- Focus on the intra-cell communication
- Implicit EDF (I-EDF) and I-EDF with FRASH provide lower latency and higher system throughput under heavy load condition and in dense networks.

Average delay of aperiodic messages



Normalized system throughput



Conclusions

- Wireless sensor networks introduce new challenges not addressed by classical ad hoc networks literature
- A scheduling based MAC protocol has been introduced to guarantee bounded message delay
- Experimental results showed the effectiveness of the proposed method

What I like

- Improving the system throughput and still having hard real-time guarantee
- Easy to do the schedulability analysis
- The cell architecture is well taken into account in the communication protocol
- Simple

Some thoughts and discussion

- If the transmissions for the inter-cell communication are different from each other, how to handle the un-balanced problem?
  - On one router, some directions may have multiple messages to send which may not be completed within the assigned frame(s); while the other directions may have no messages to send. (This is always happening in sensor networks.)
  - Also, different routers may have different message lengths on the same direction.
  - FRASH is only used in intra-communication. Inter-cell communication is not addressed and still open.
- Timeliness is only considered within a cell by EDF, the same idea is used in uni-processor scenario for a long time. What's the difficulty or difference here?