A Configurable Medium Access Control Protocol for IEEE 802.15.4 Networks

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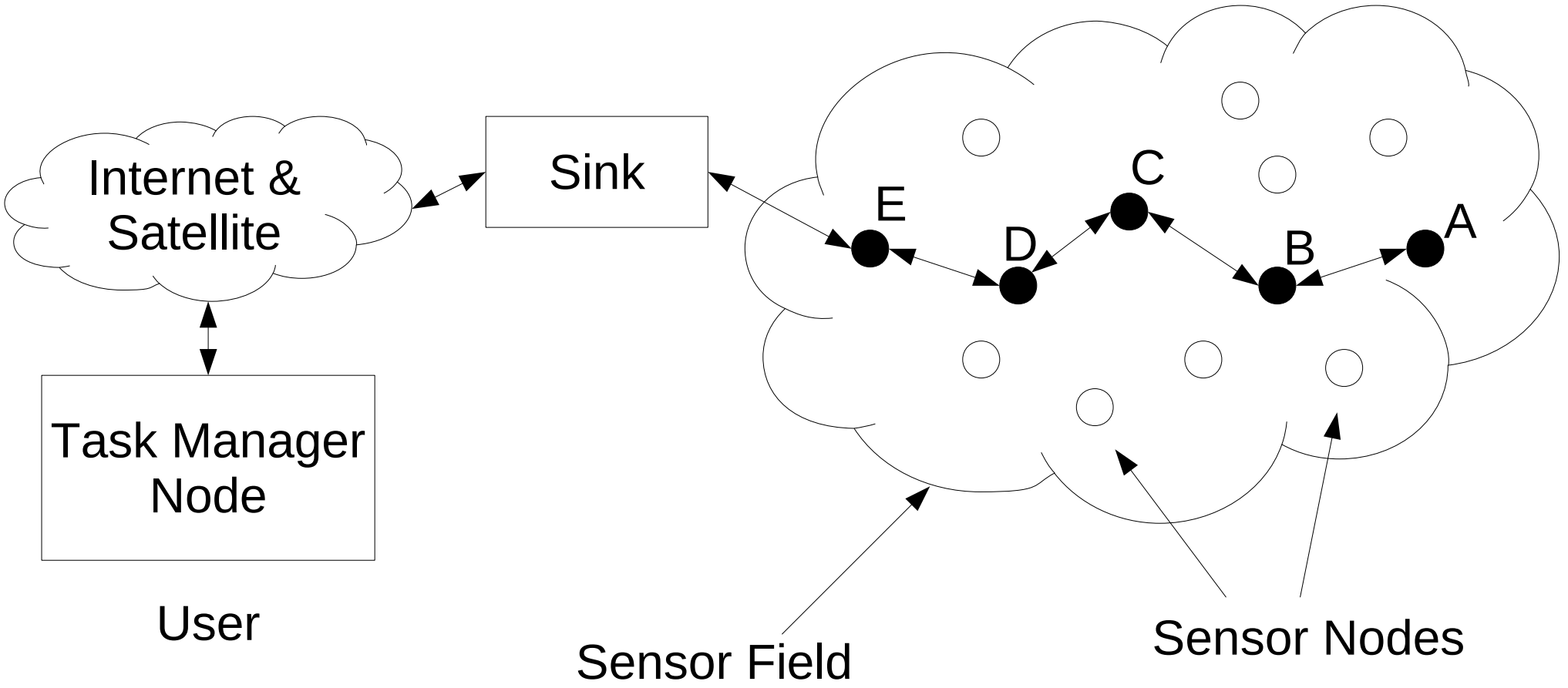
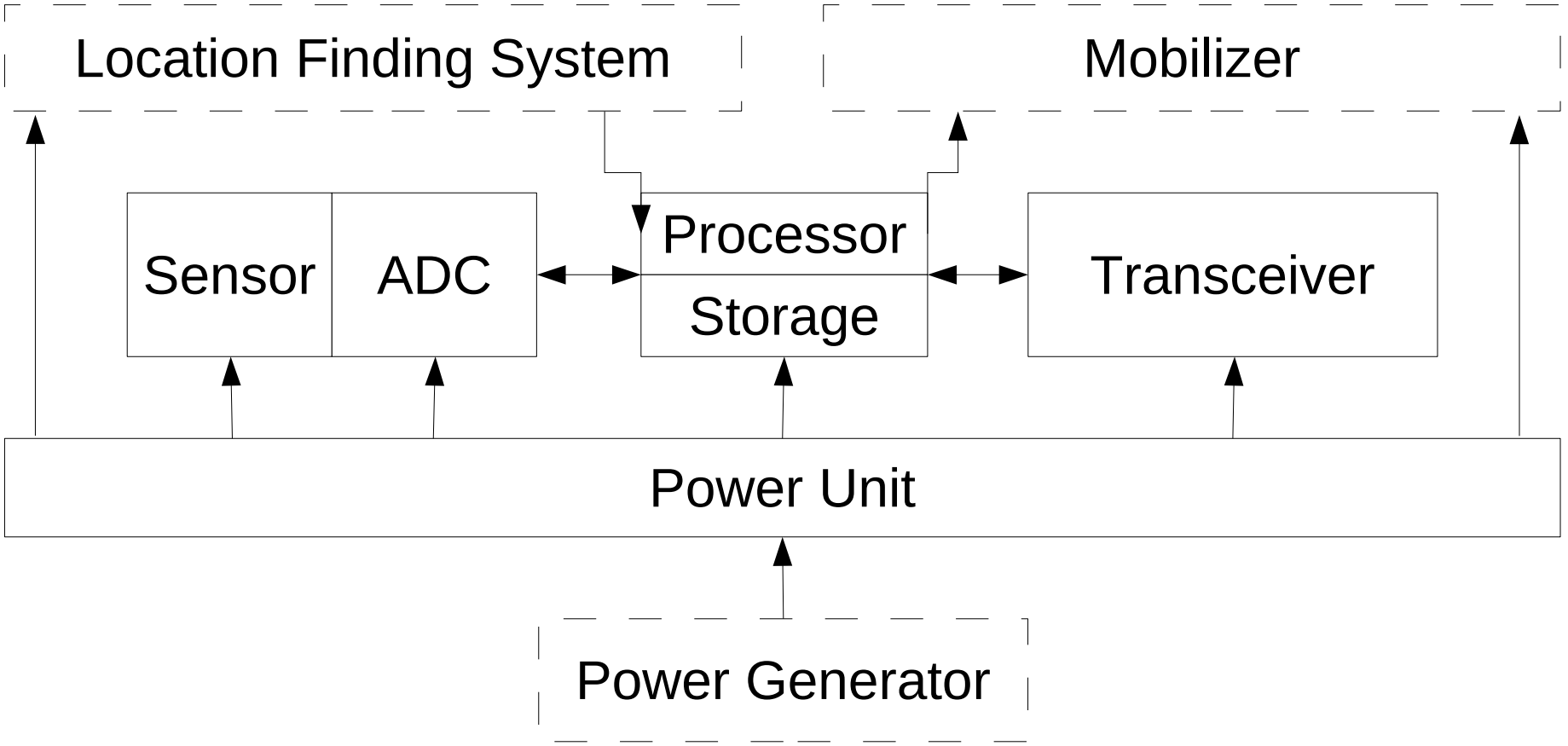
Wireless Sensor Networks



WSN architecture [Akyildiz et al. 2002]

Wireless Sensor Networks

- Sensor Nodes



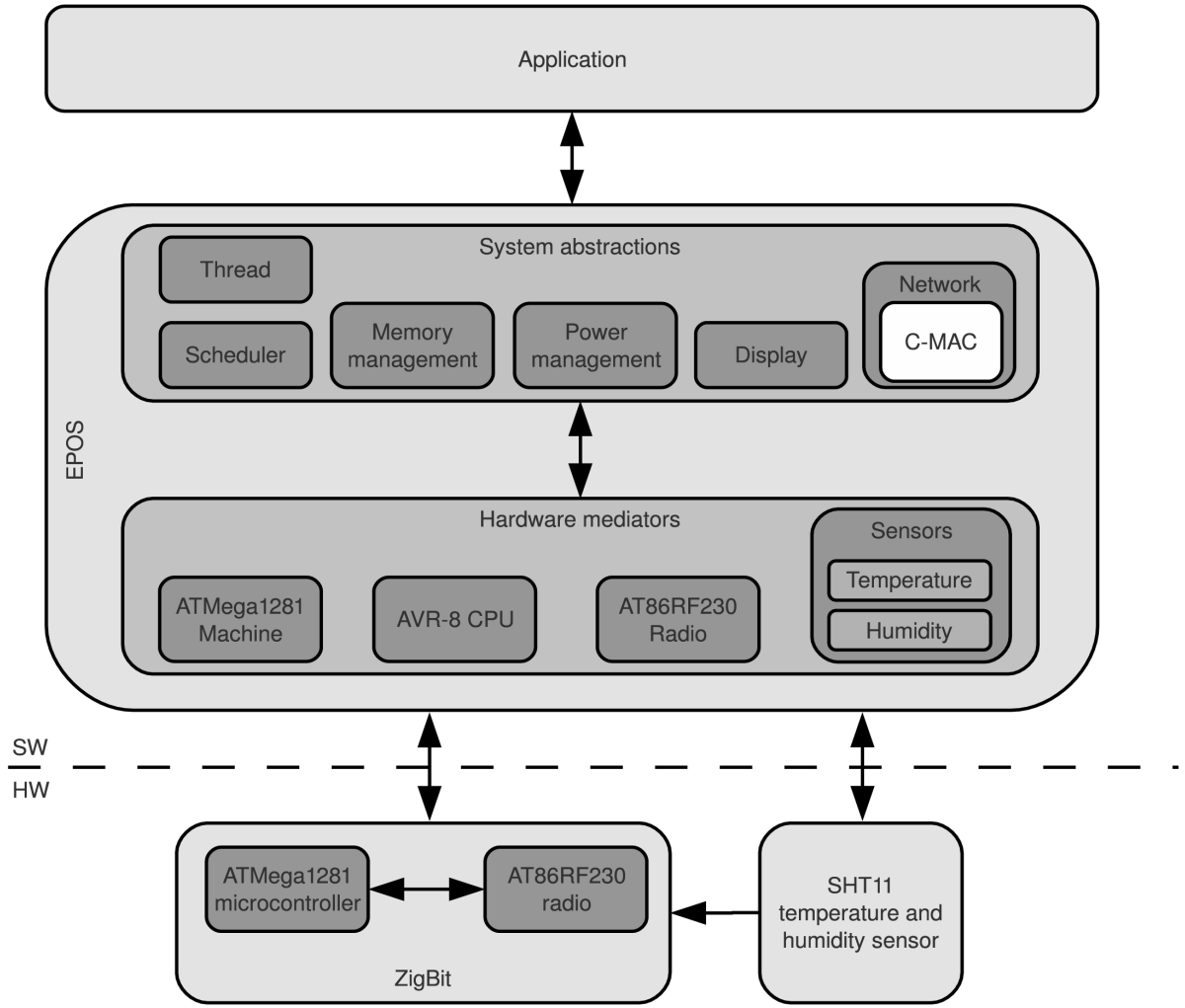
Sensor Nodes components [Akyildiz et al. 2002]

Wireless Sensor Networks

- EPOS Mote I (http://epos.lisha.ufsc.br/)

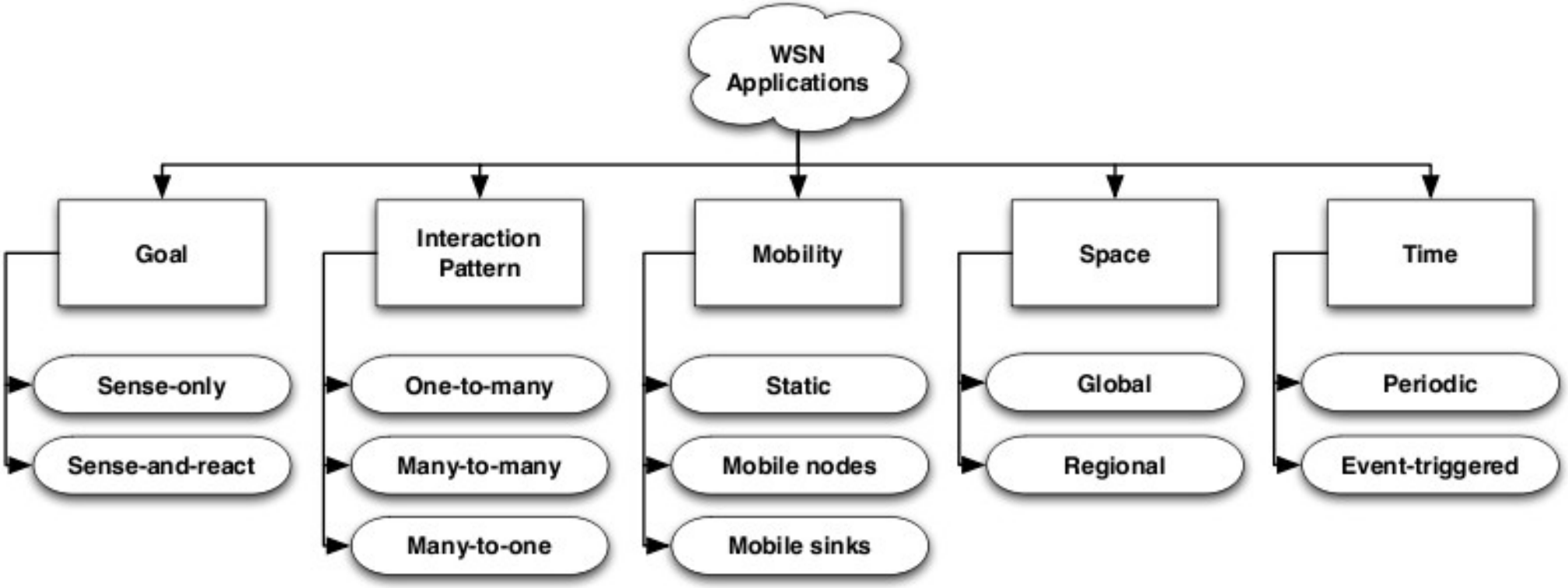
Wireless Sensor Networks

- EPOS Mote I – Architecture Overview
- 7.37 MHz 8-bit CPU
- 2.4 GHz Radio
- 128 kB Flash
- 8 kB SRAM
- 4 kB EEPROM



WSN Applications

- Different applications => Different requirements



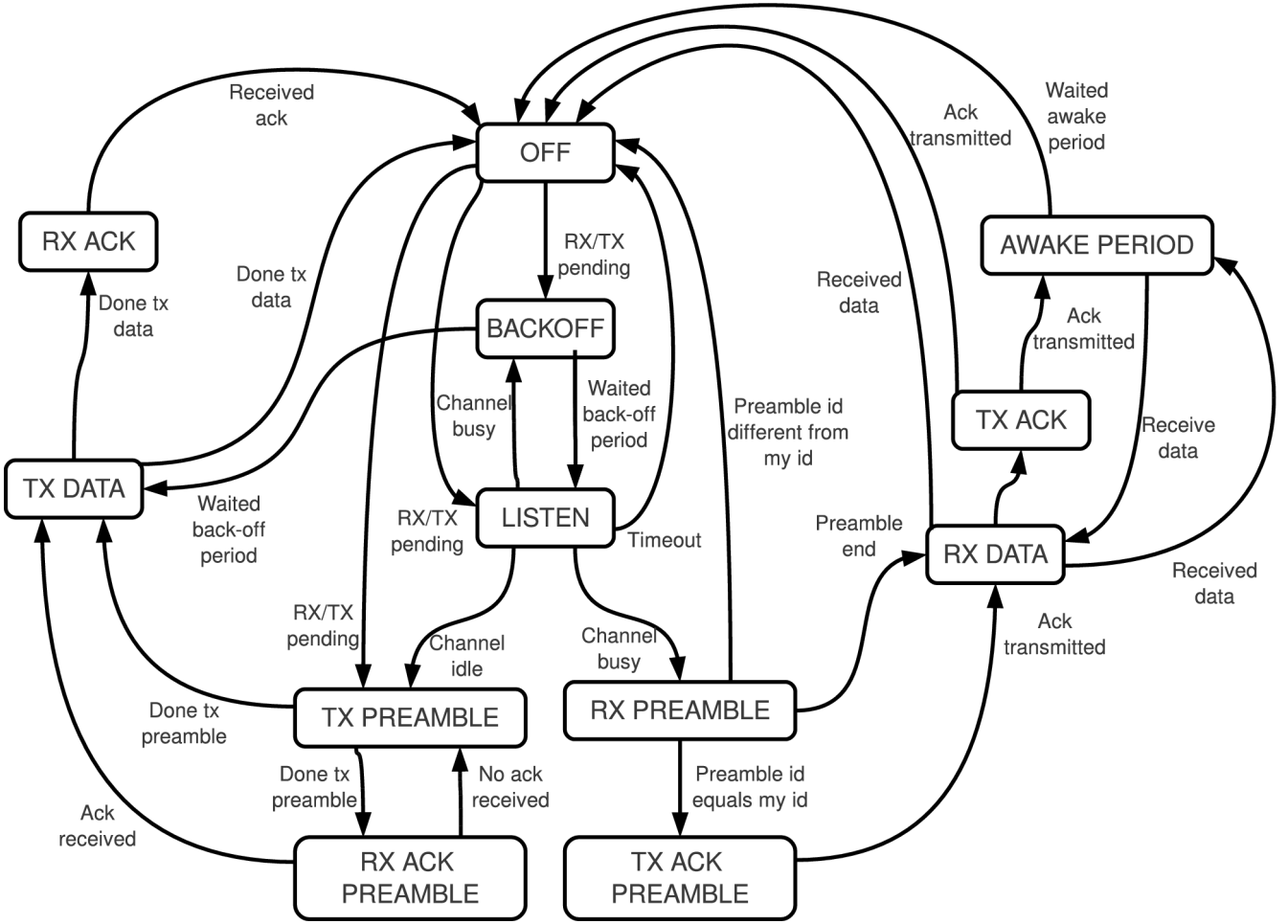
WSN applications taxonomy [Mottola 2010 (to appear)]

Motivation

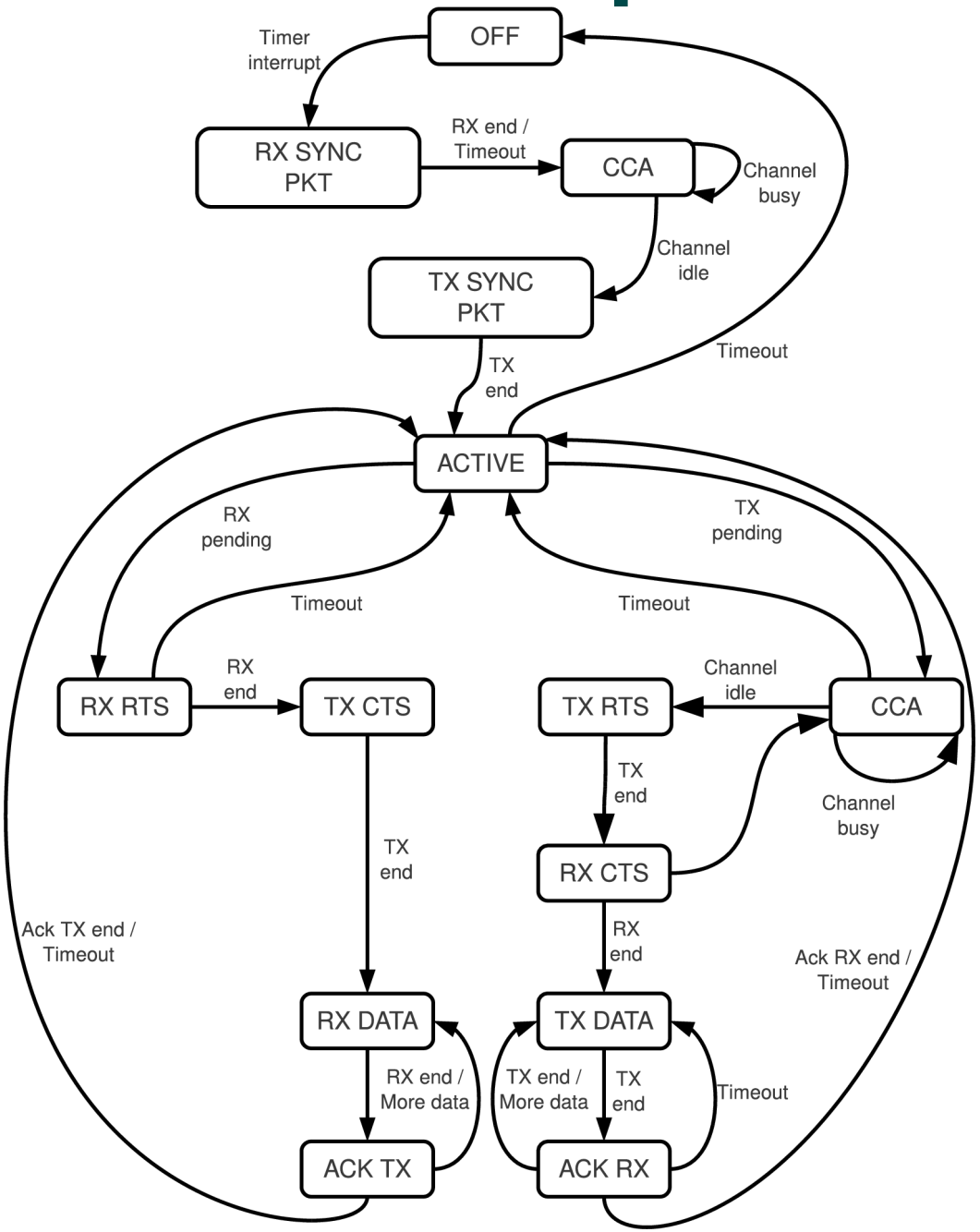
- Different requirements => Different protocols
- Categories
  - Channel polling
  - Scheduled contention
  - TDMA-based
  - Hybrid

- Configurable Medium Access Control protocol
  - Enable application-specific protocols
  - Configurability not at expense of performance

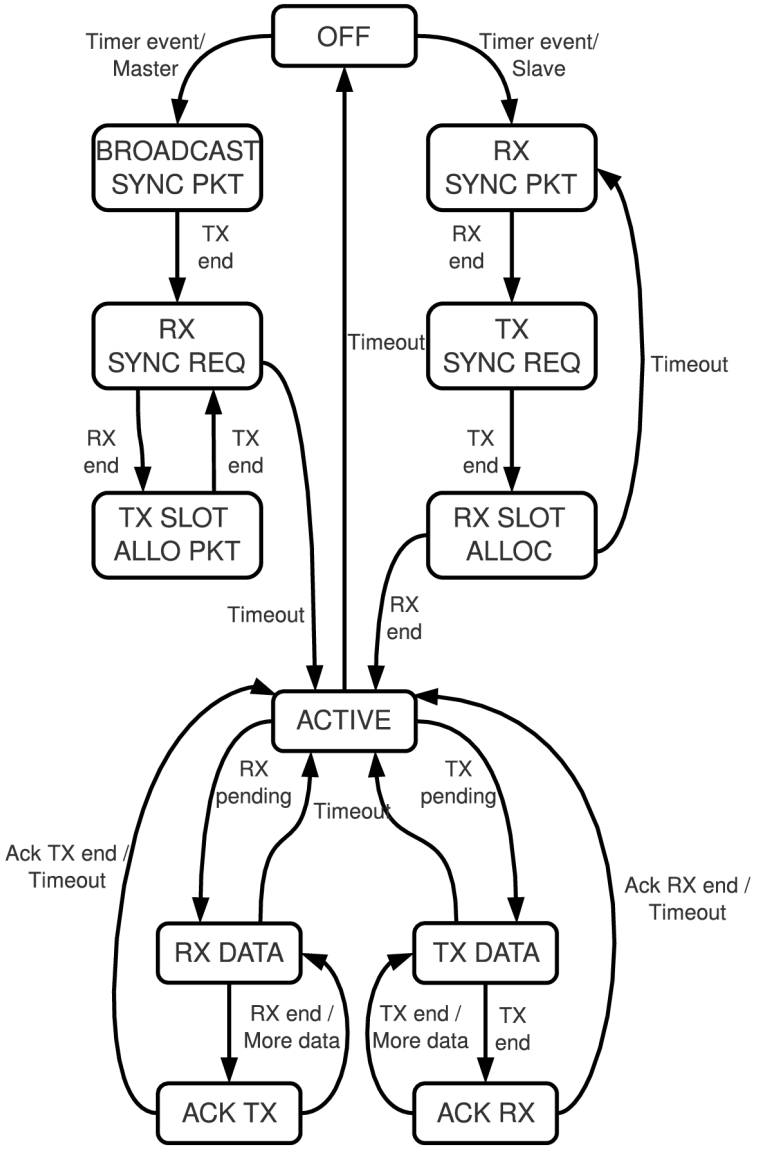
Channel polling protocols



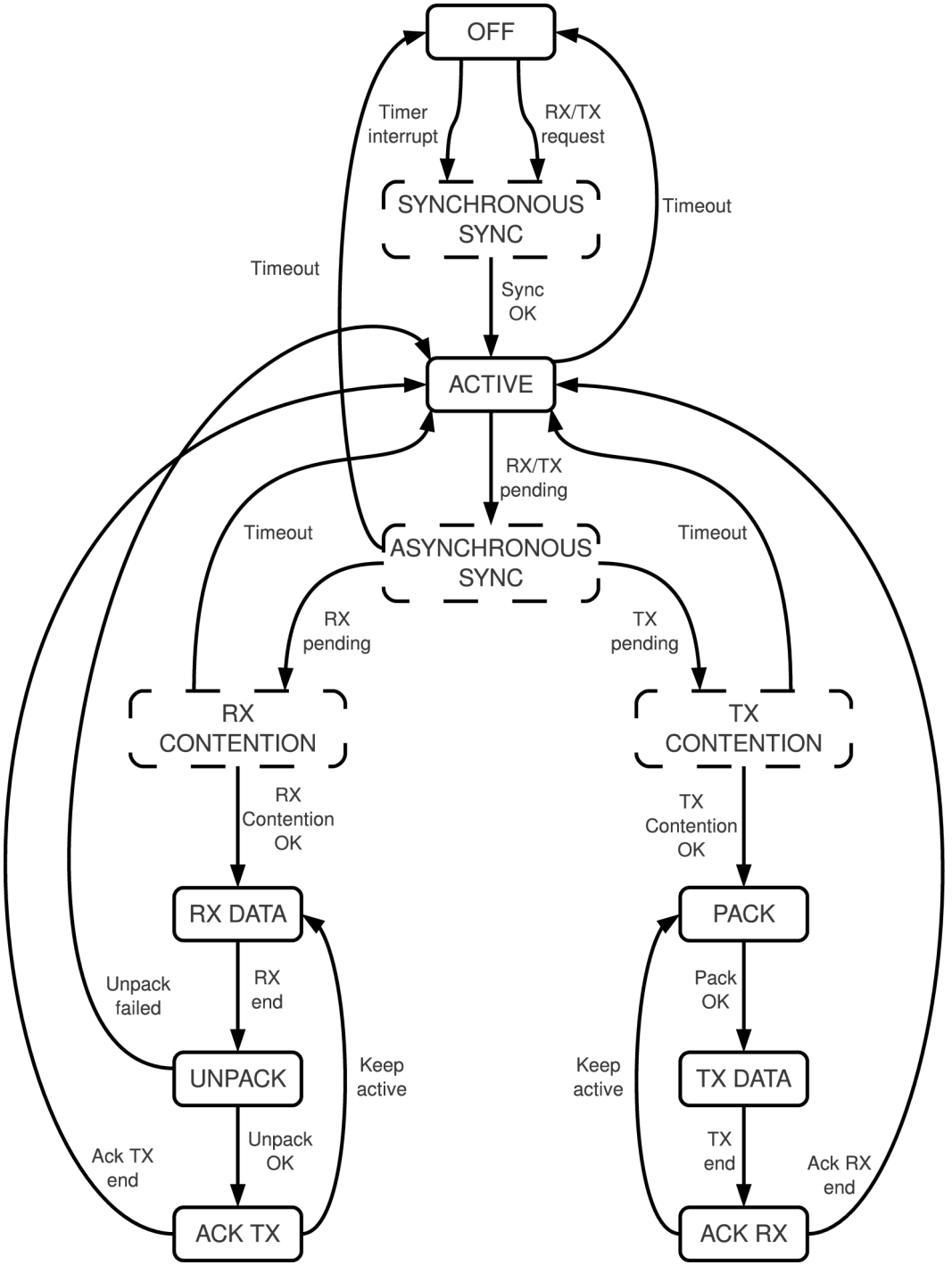
Scheduled contention protocols



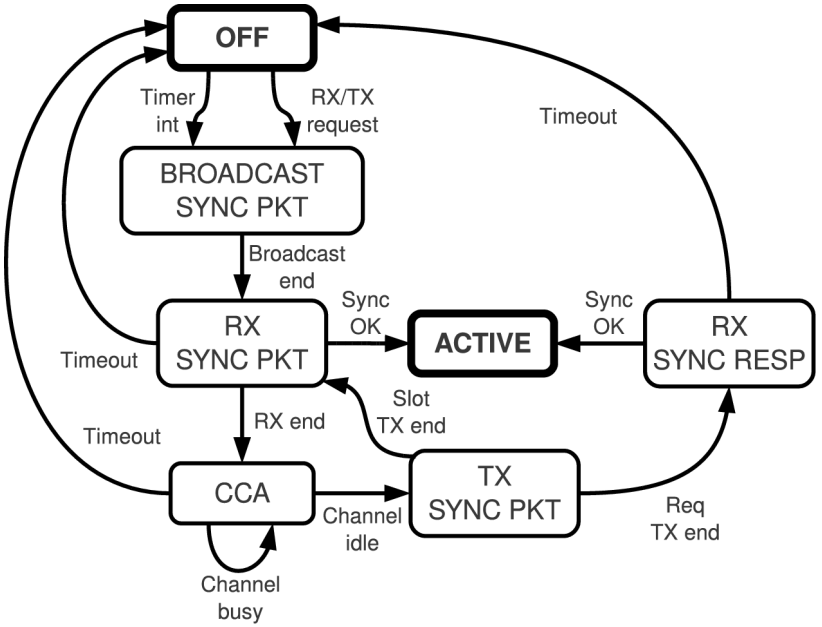
TDMA-based protocols



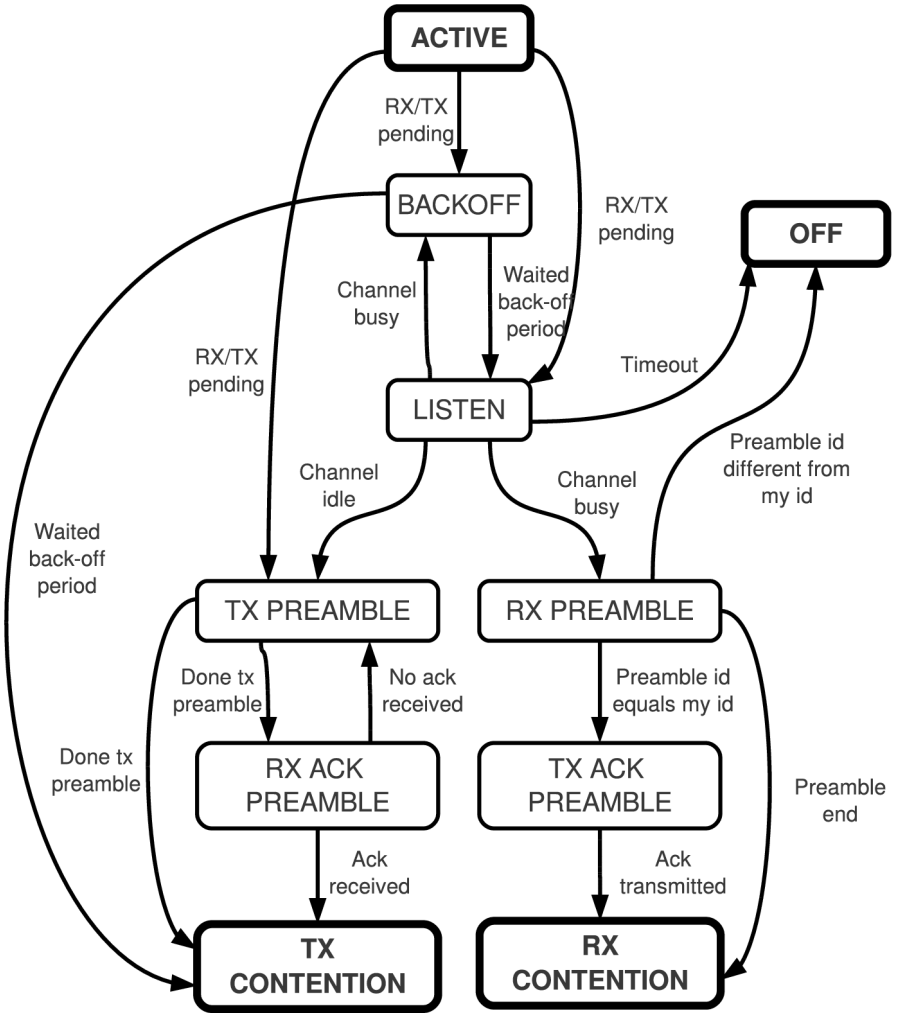
C-MAC


OFF
Timer interrupt
RX/TX request
SYNCHRONOUS SYNC
Timeout
Timeout
Sync OK
ACTIVE
RX/TX pending
Timeout
ASYNCHRONOUS SYNC
Timeout
RX pending
TX pending
RX CONTENTION
TX CONTENTION
RX Contention OK
TX Contention OK
RX DATA
PACK
Unpack failed
RX end
Pack OK
Keep active
UNPACK
TX DATA
Keep active
Unpack OK
TX end
Ack TX end
Ack RX end
ACK TX
ACK RX

C-MAC

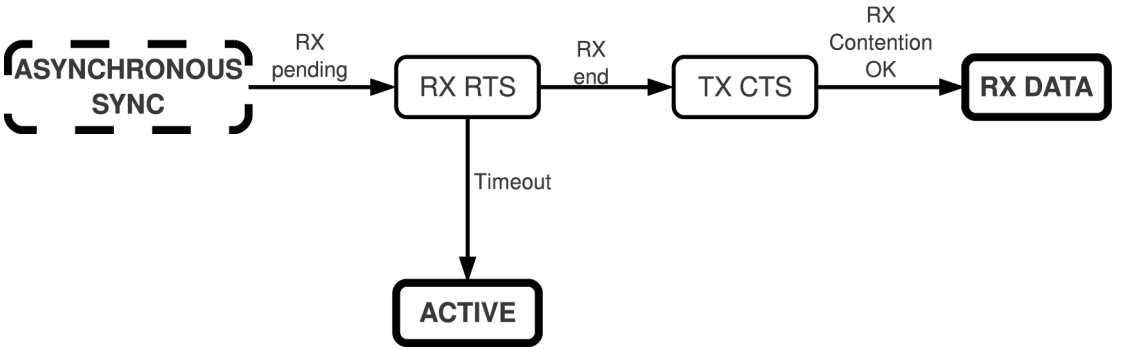


Synchronous Sync

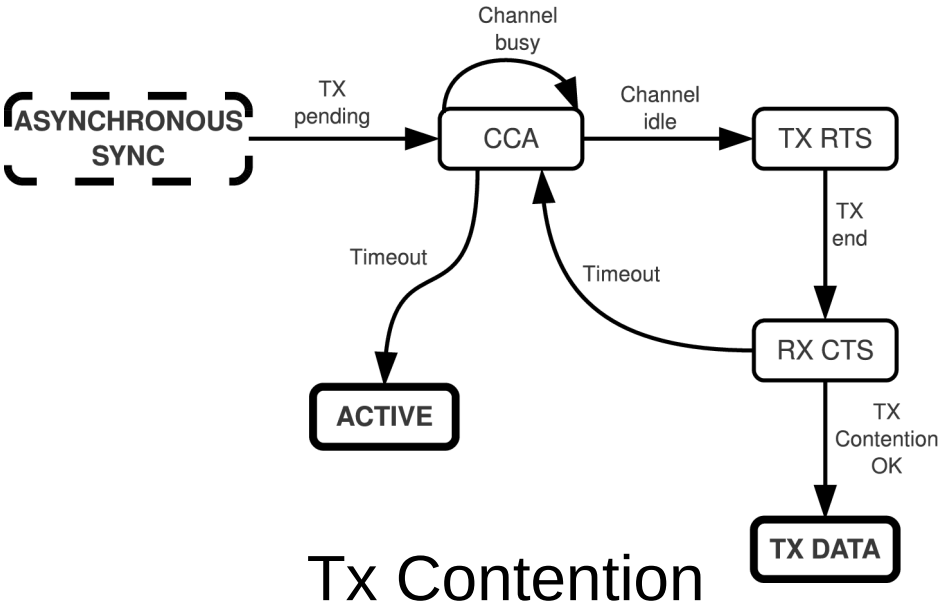


Asynchronous Sync

C-MAC



Rx Contention



Tx Contention

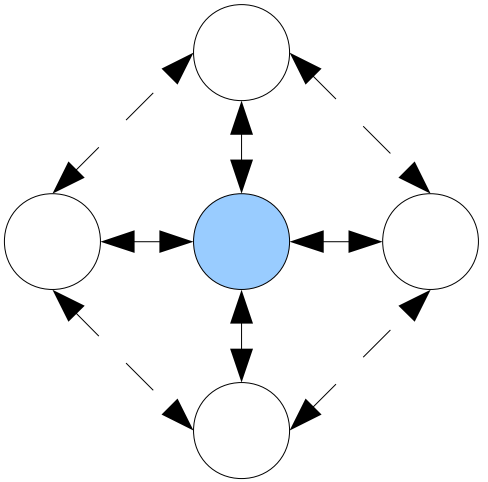
Experiments

- Configurations evaluated
  - Beacon-enabled IEEE 802.15.4
  - Non-beacon IEEE 802.15.4
  - Non-beacon IEEE 802.15.4 without CSMA-CA
  - Non-beacon IEEE 802.15.4 without ACK
  - Non-beacon IEEE 802.15.4 without both CSMA-CA and ACK

Experiments

- Configuration parameters and network topology

Parameter	Value
Compiler	GCC 4.0.2
Microcontroller clock	1 MHz
Packet size	64 bytes
Tx power	3 dBm
Beacon order	7
Superframe order	4
Duty cycle	12%



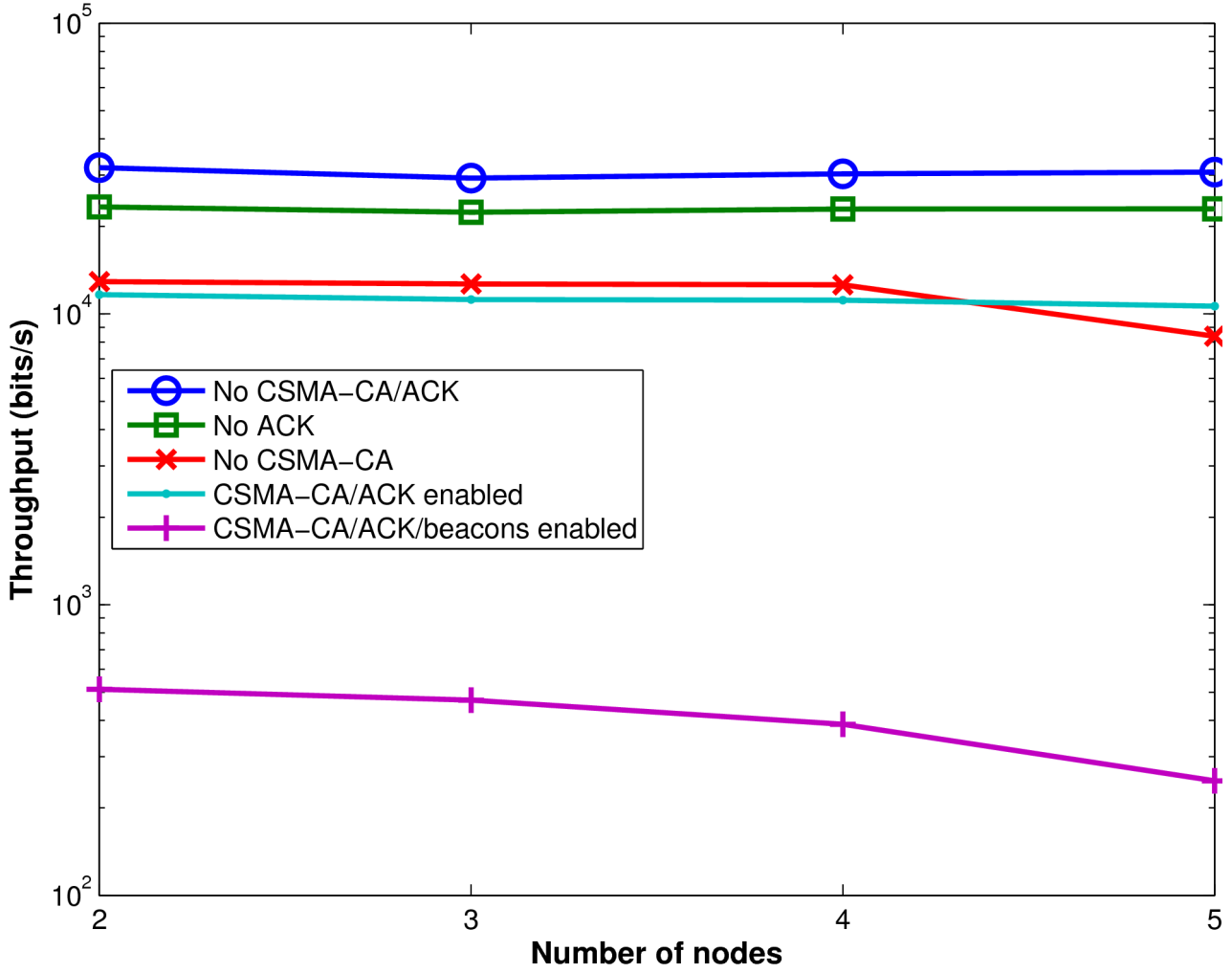
Results

- Memory Footprint

Configuration	Code (bytes)	Data (bytes)
No CSMA-CA / ACK	**3248**	**185**
No ACK	**3572**	**185**
No CSMA-CA	**3768**	**202**
CSMA-CA / ACK enabled	**4092**	**202**
CSMA-CA / ACK beacons enabled	**5344**	**215**

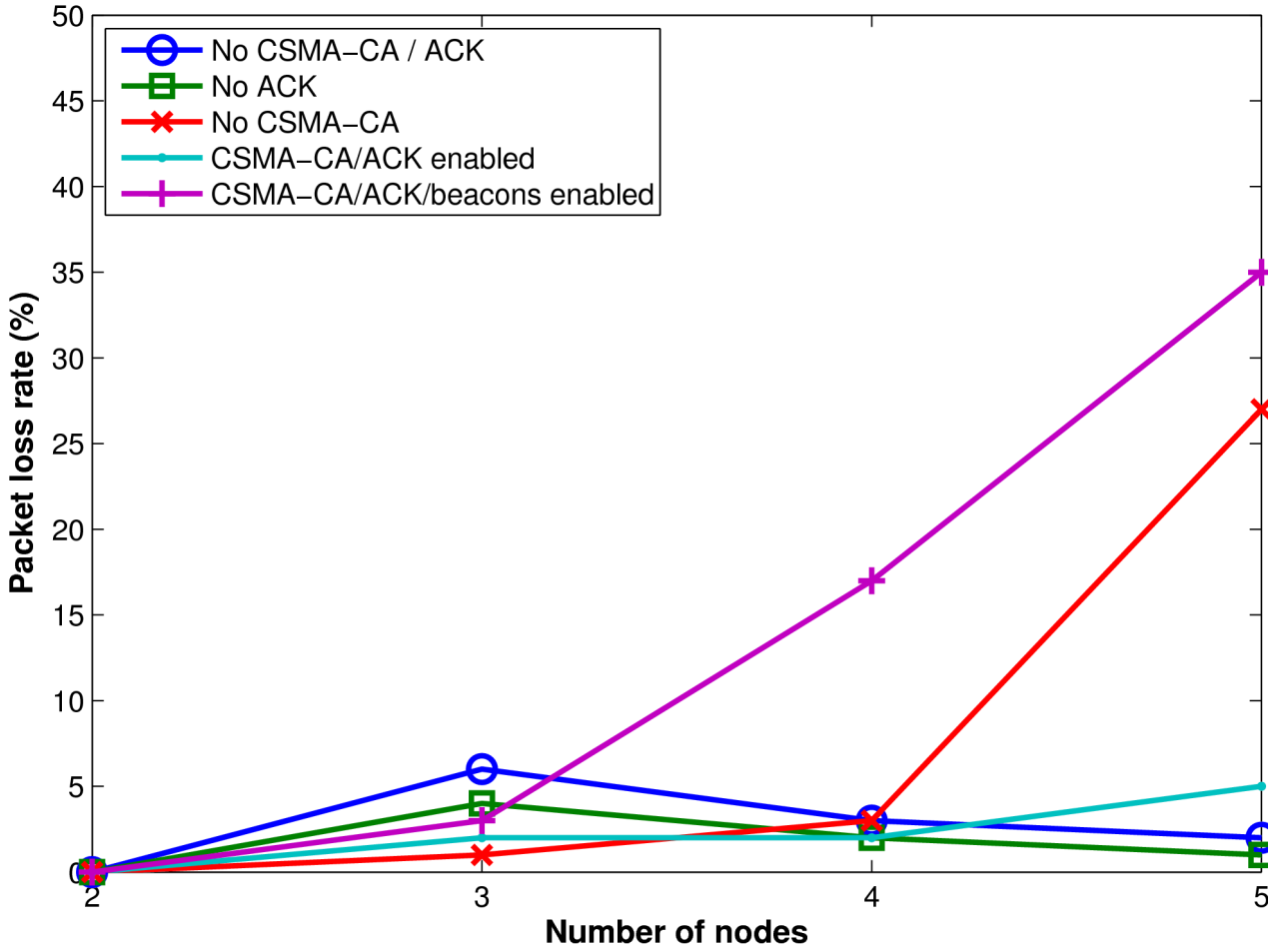
Results

- Average network throughput (logarithmic scale)



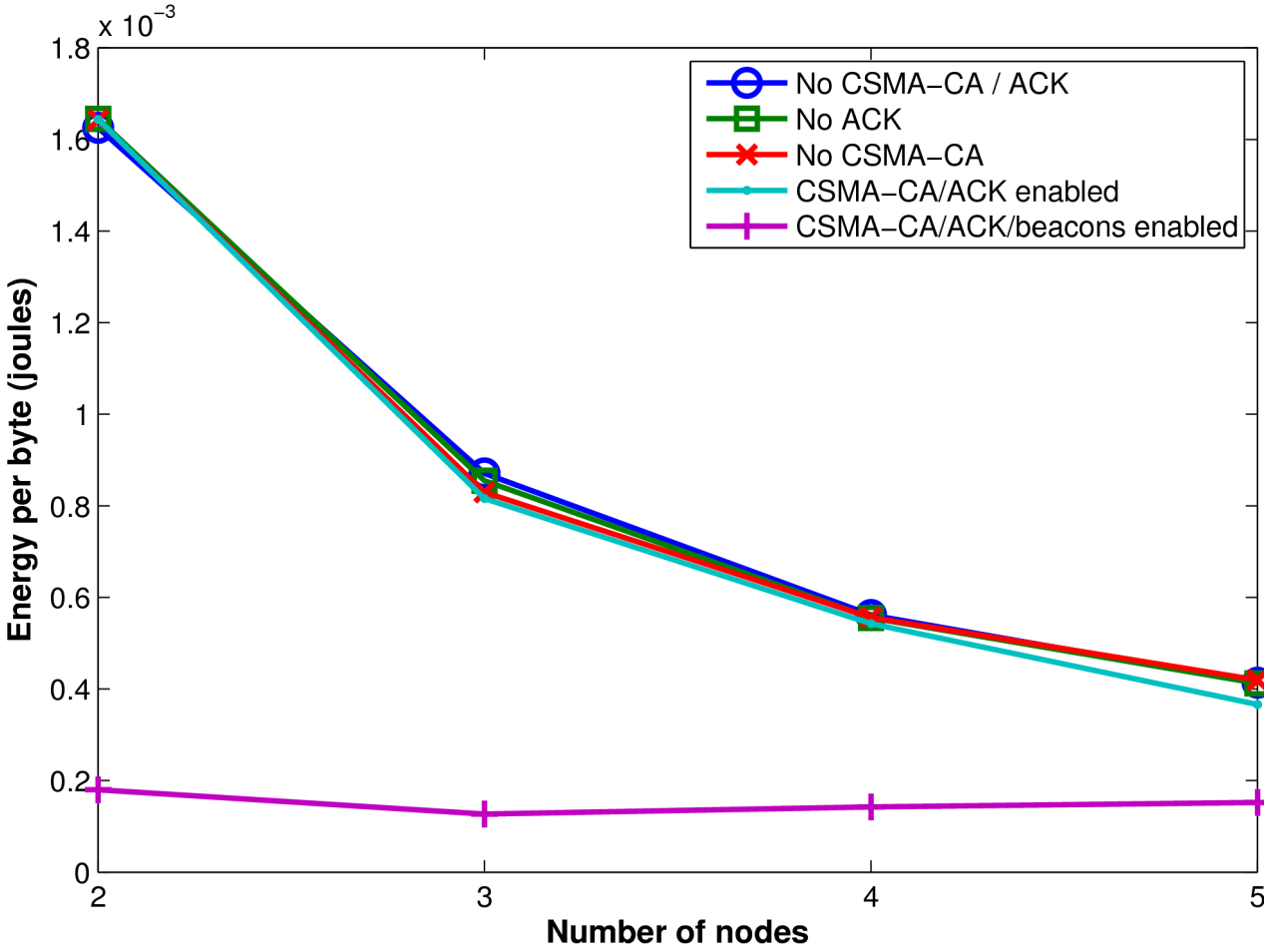
Results

- Average packet loss rate



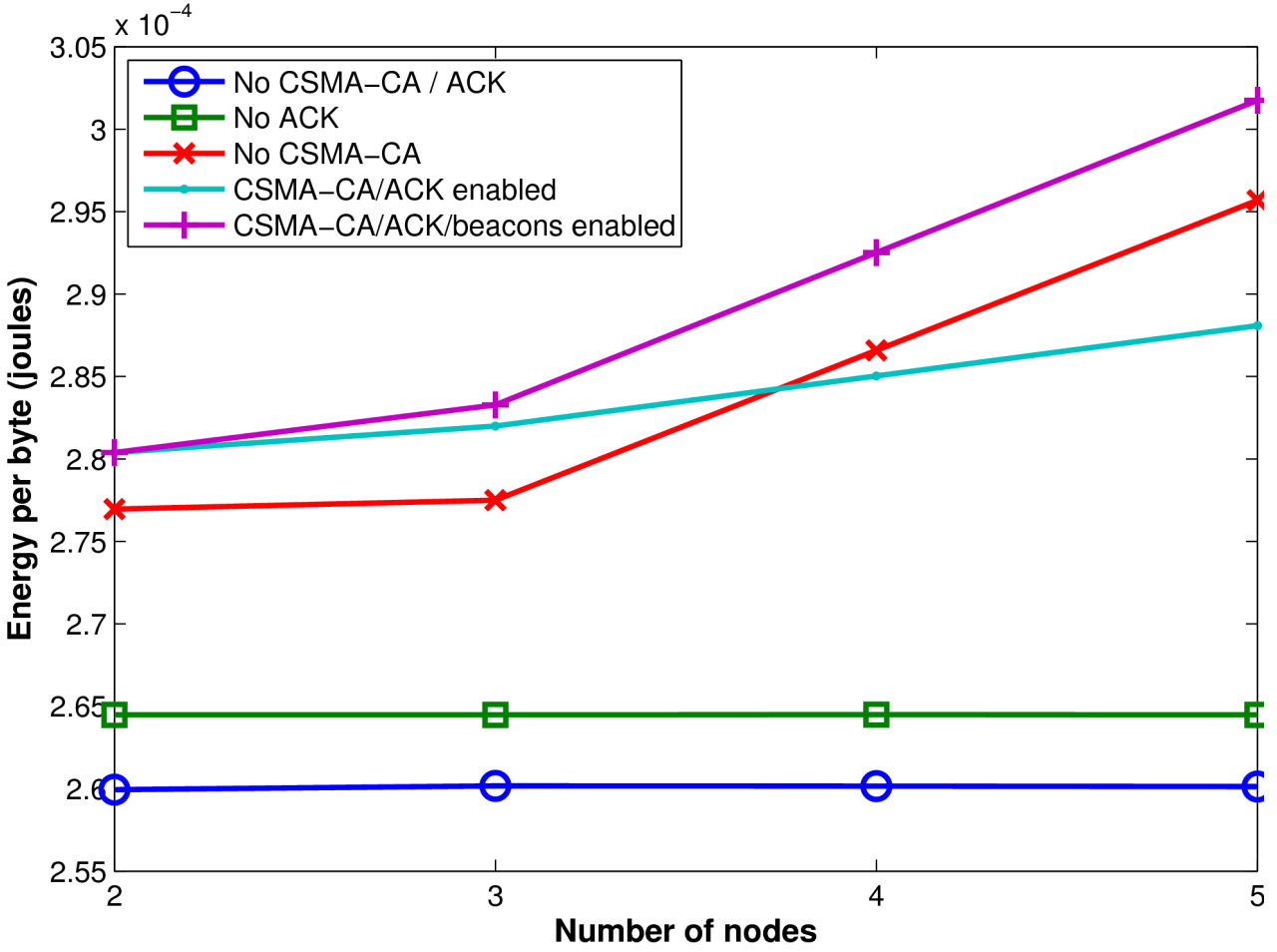
Results

- Energy consumed per byte received on the coordinator



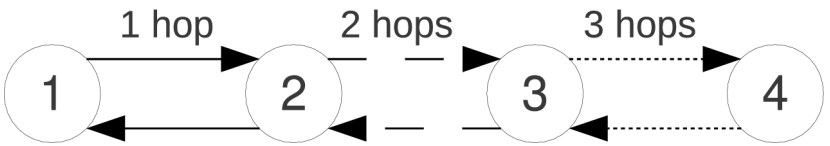
Results

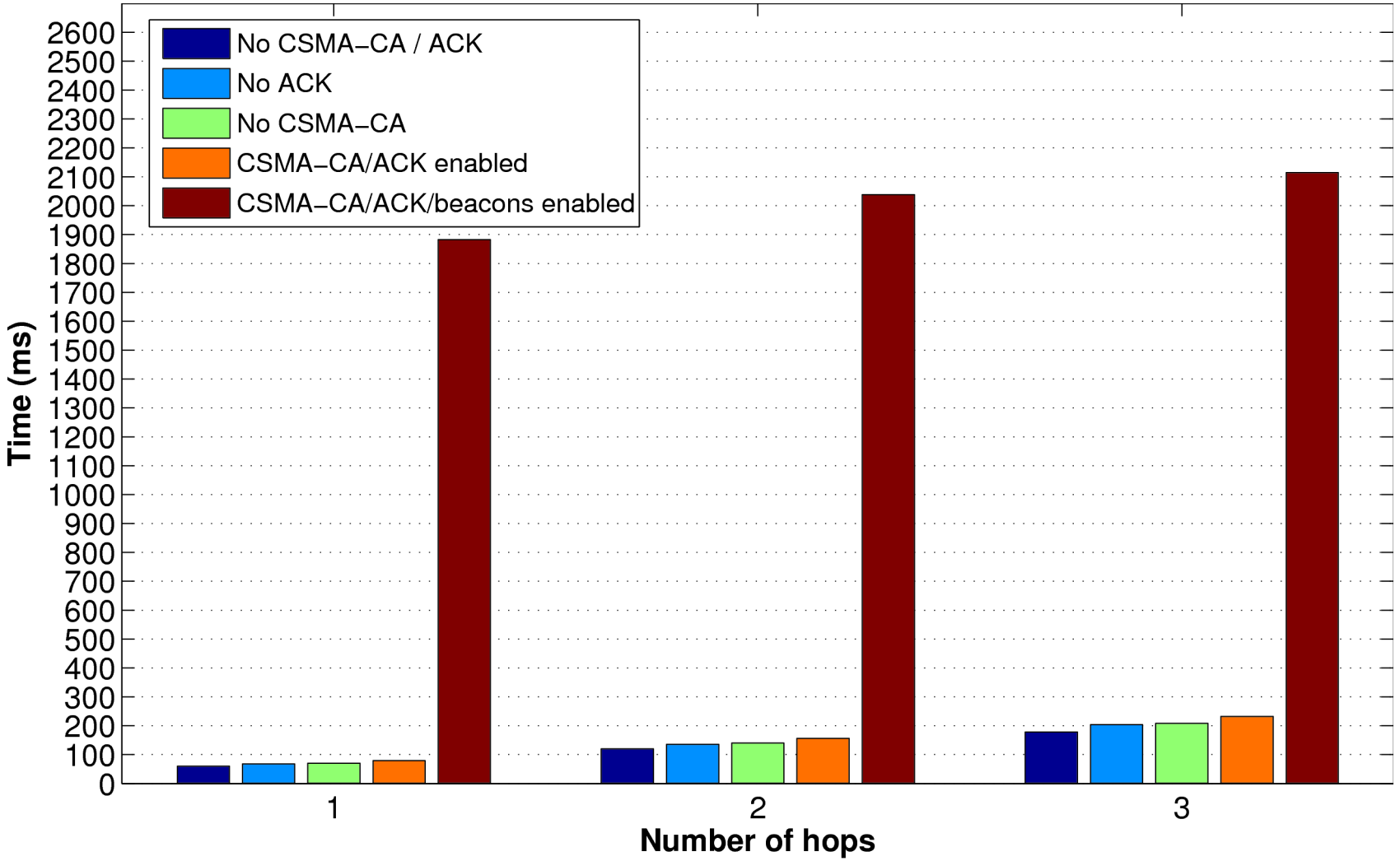
- Energy consumed per byte sent on the leaf nodes



Results

- Round-trip time





Results

- C-MAC vs ZigBeeNet

Configuration	Code (bytes)	Data (bytes)	RTT (ms)
C-MAC IEEE 802.15.4	4092	202	79
ZigBeeNet IEEE 802.15.4	26776	289	62

Conclusions

- C-MAC is operational
  - Configuration is not automated, but can be easily done
  - Configurability achieved by metaprogramming techniques
  - Good performance

- Perspectives
  - Dynamic changes in protocol behavior
    - Reactive adaptation of parameters (e.g. duty cycle)
    - Coordinated protocol alterations (aided by a meta-protocol)
  - Cross-layer optimizations
    - Protocol and service integration
      - Routing, transport, localization
      - HECOPS
      - Ant-based Hybrid Routing