AMAC: Traffic-Adaptive Sensor Network MAC Protocol through Variable Duty-Cycle Operations

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Motivation

Problems of existing WSN MAC protocols

- ***<u>Fixed duty cycle</u>***: Each node has the same periodic interval (cycle time).
- Energy vs. latency tradeoff
  - Increasing cycle time can save energy but increase communication latency
  - Decreasing cycle time decrease latency but increase energy consumption

AMAC motivation

- Is it possible to have a variable duty cycle (variable cycle time)
  - <u>**Minimize idle listening** for idle nodes</u>
  - <u>**Maximize performance** for busy nodes on the communication path</u>

AMAC

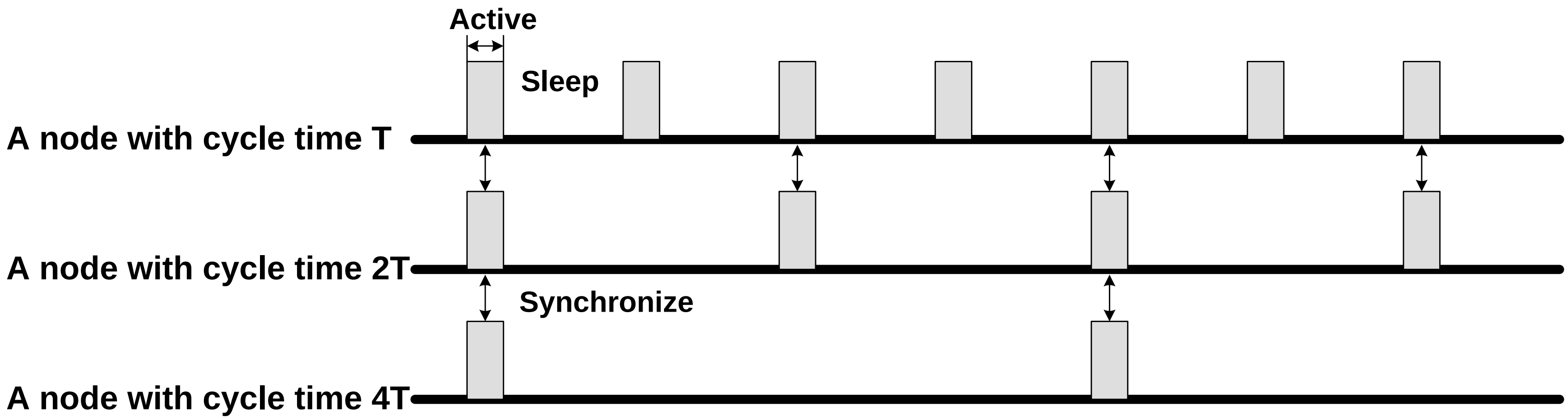
- **Variable duty cycle**
  - Each node employs a different duty cycle depending on the traffic
- **Variable active period**
  - Each node can dynamically adjust *the duration of its active period*

AMAC: Variable Duty Cycle

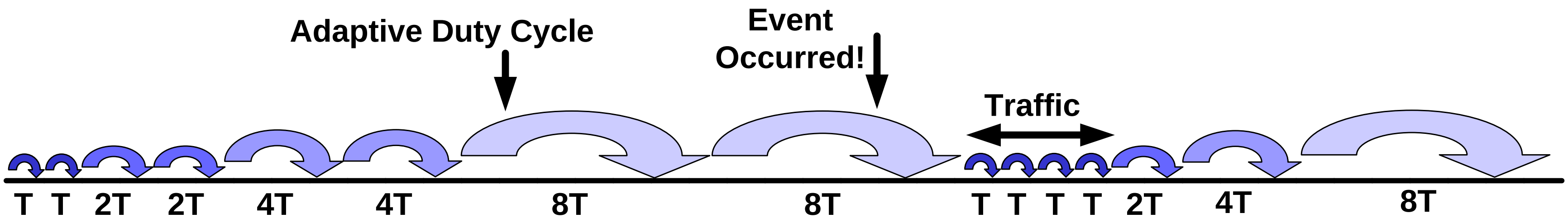
- **Each node can have a variable cycle time.**
  - Busy nodes on the communication path have a short cycle time to reduce latency
    - If there is traffic
      - Receiver reduces its cycle time to minimum cycle time (T)
  - Idle nodes have a long cycle time to minimize idle listening
    - If there is no traffic
      - Each node doubles their cycle time automatically.

- **2^N variation of cycle times: T, 2T, 4T, 8T, …**
  - Faster nodes can always synchronize with slower nodes
  - Every node doubles their clock cycle time on natural alignment boundary to avoid offset skew.
    - For example, a cycle time of 8T must start on 0T, 8T, 16T, 24T, etc.

AMAC: Variable Duty Cycle



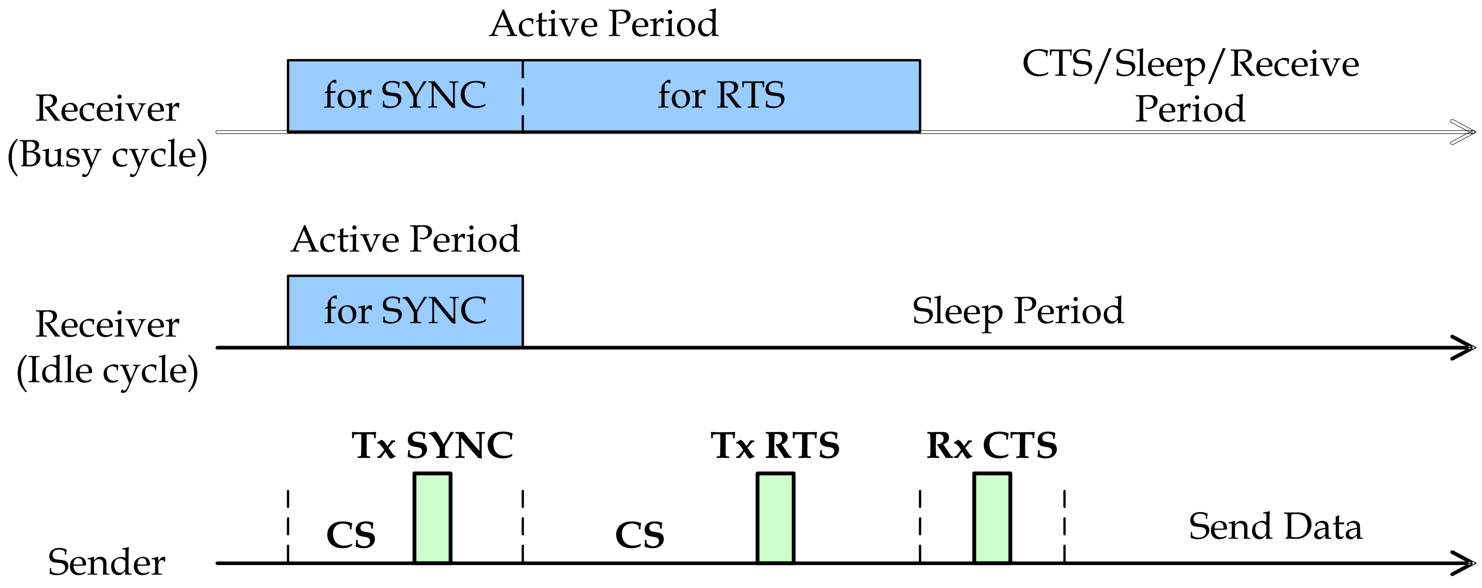
(a)



(b)

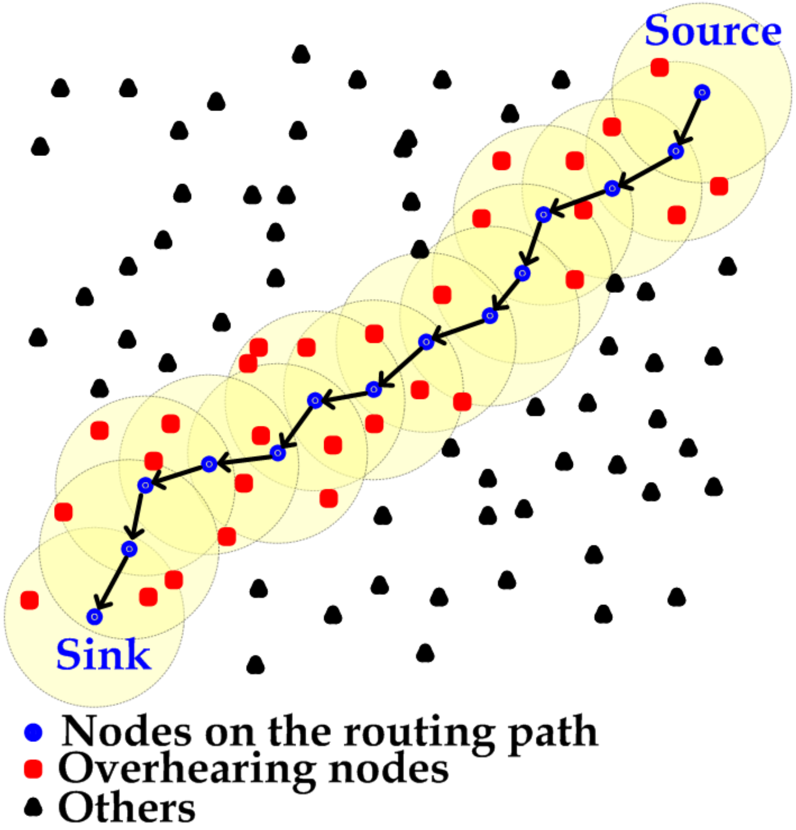
AMAC: Variable Active Period

- **Remove the unnecessary RTS period during idle cycle**
  - **Communication SYNC**
    - A sender transmits it to notify the presence of traffic.
    - Can use the ordinary clock SYNC packet with an extra bit field
  - If a node receives communication SYNC, it extends its active period.
    - Each node can dynamically adjust the duration of its active period.



Experimentation

- **The network topology and design parameters used for simulations**



Protocol and packet format parameters	
Parameters	Values assumed
Control packet length	10 bytes
Data packet length	200 bytes
Contention window	for SYNC: 31 slots for others: 63 slots
Energy	Tx: 31mW Rx and Idle: 15mW
Minimum cycle time, T	361 ms
Maximum cycle time, 64T	23,104 ms

A-MAC vs. S-MAC

S-MAC

- Fixed cycle time of 4T.

A-MAC

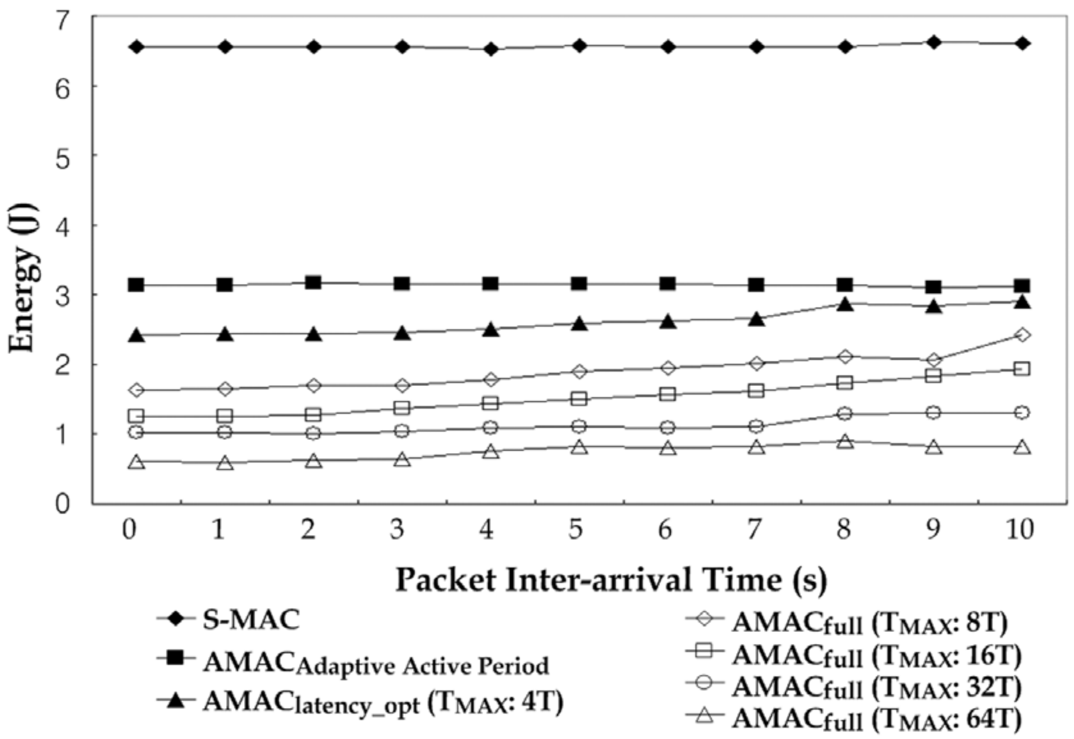
- $AMAC_{variable\_active\_period}$ (Tmin = 4T, Tmax = 4T)
  - Variable active period only
- $AMAC_{latency\_opt}$ (Tmin = T, Tmax = 4T)
  - Latency optimization
- $AMAC_{full}$ (Tmin = T, Tmax = 8T to 64T)
  - Full AMAC.

Traffic pattern

- The source generates 100 messages, each of which is 200 bytes long.
- We vary the traffic load by changing the packet inter-arrival time on the source node from 0 to 10 seconds.

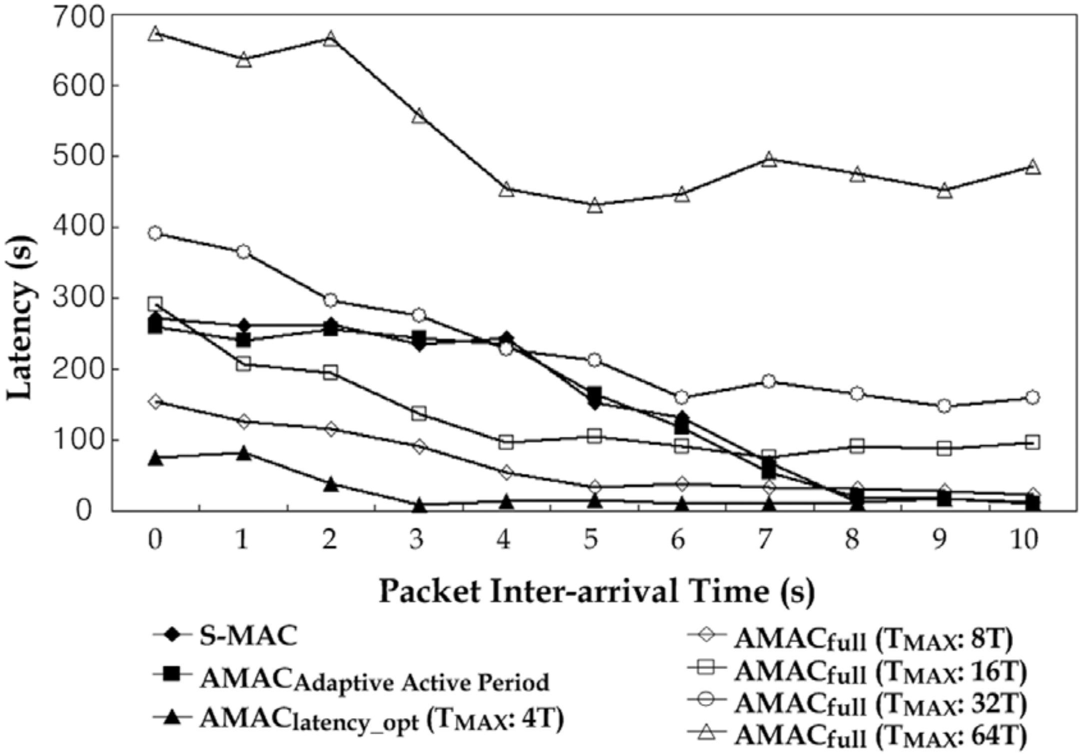
Energy Consumption

- **The average per-node energy consumption in delivering 100 packets**
  - $AMAC_{variable\_active\_period}$ can halve the energy consumption of S-MAC.
  - $AMAC_{latency\_opt}$ not only can reduce the latency but also can save energy effectively
  - $AMAC_{full}$ can further reduce the energy consumption (up to an order of magnitude)



Average Packet Latency

- As you increase the packet inter-arrival time, the latency diminishes.
  - The delay due to the contention is reduced.
- $AMAC_{latency\_opt}$ is very effective in reducing the latency
- $AMAC_{full}$ is
  - Good for burst or high traffic (T_{MAX}: T, 2T, 4T, 8T)
  - Latency increase is substantial for low traffic (T_{MAX}: 16T, 32T)



Conclusion

- **AMAC is fundamentally different from existing protocols**
  - Each node can dynamically adjust
    - Duration of an active period
    - Duration of a duty cycle
- **Variable duty-cycle operation allows us to achieve both high performance and low energy consumption at the same time.**
  - Busy nodes can work with the highest duty-cycle.
  - Idle nodes can work with the lowest duty-cycle.