A scalable causal broadcast that tolerates dynamics of mobile networks

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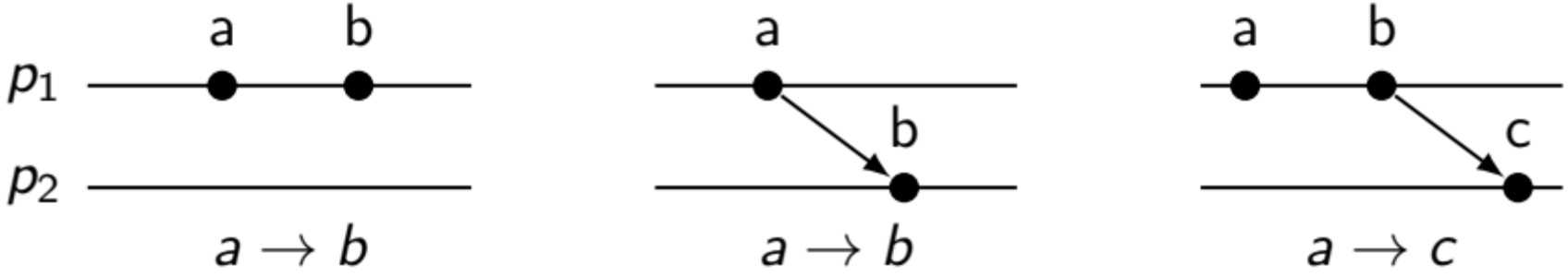
Causal broadcast

- **Causal order** is defined by the **Happened-Before** relation, which orders events following three rules:



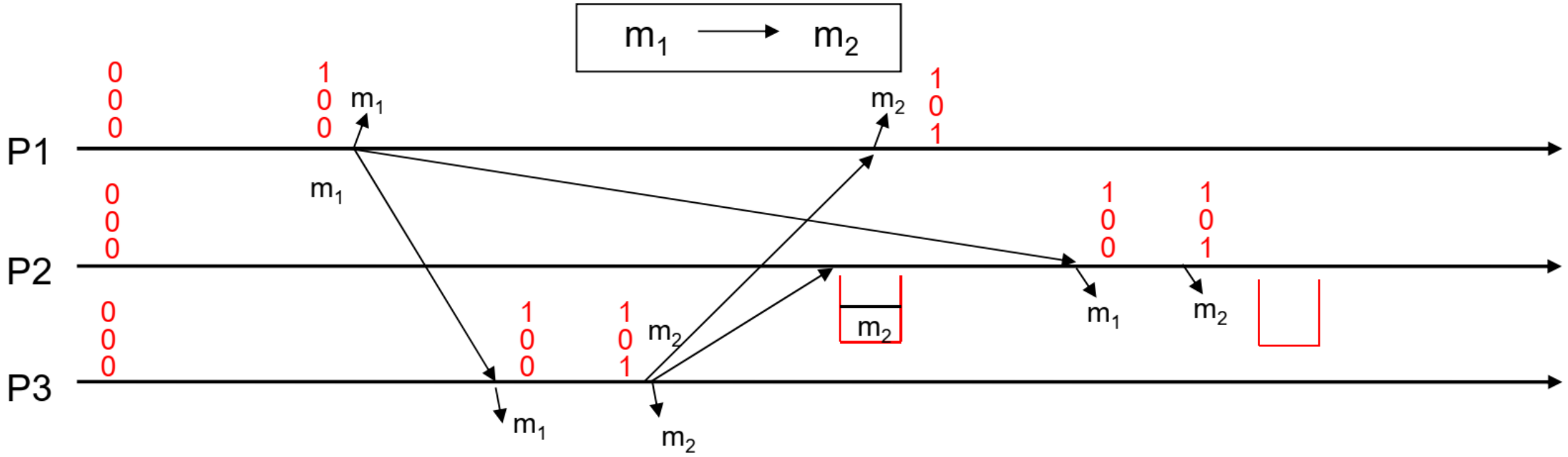
- **Causal broadcast**

  Processes **deliver** each message exactly once in causal order:
  $\forall m1, m2$,broadcast($m1$)→broadcast($m2$)⇒ deliver($m2$)↛deliver($m1$)

⇒ Control mechanism + reception of a message it's delivery

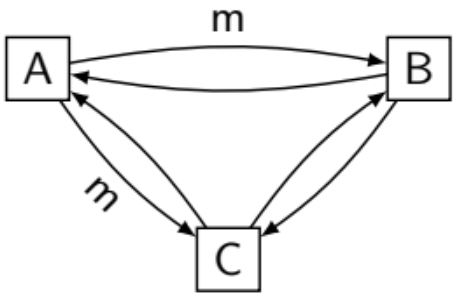
Vector clock approach

- A vector clock with one entry per node piggybacked on message

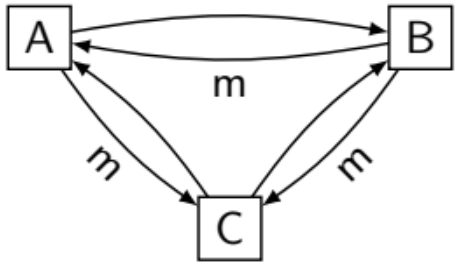


$\Rightarrow$ not scalable

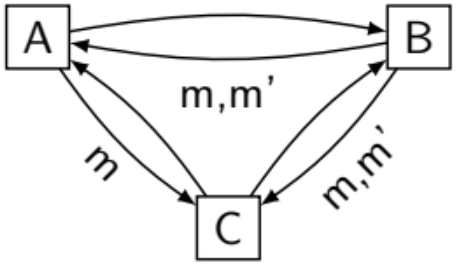
Fifo approach



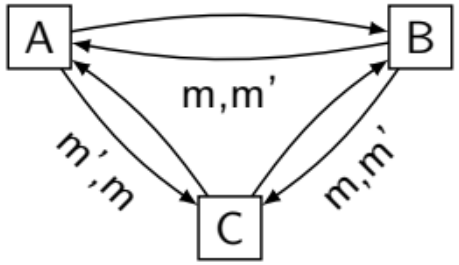
(a) A broadcast(m)



(b) B receives, delivers, and forwards m



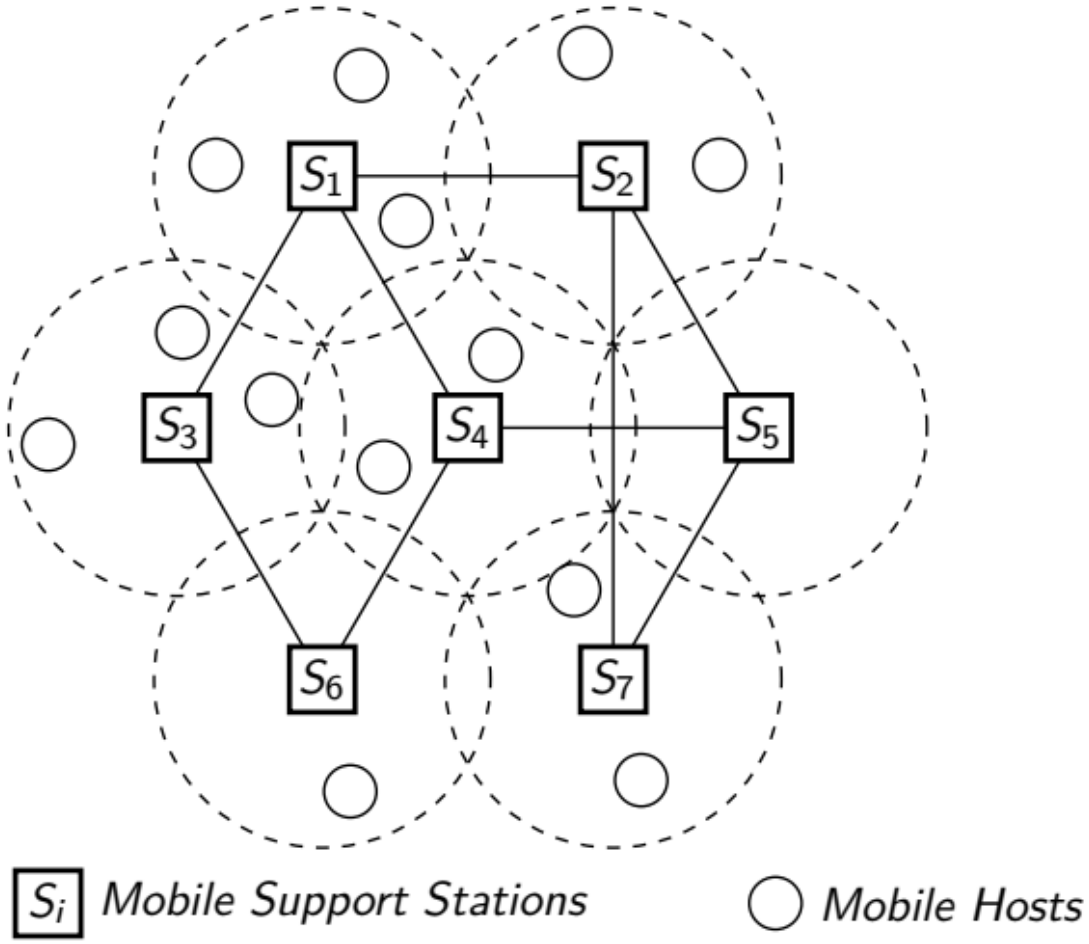
(c) B broadcast(m')



(d) A receives, delivers and forwards m'
C receives and delivers m, then m'

- No control information to order messages
- Hard to add new communication channels

Mobile networks



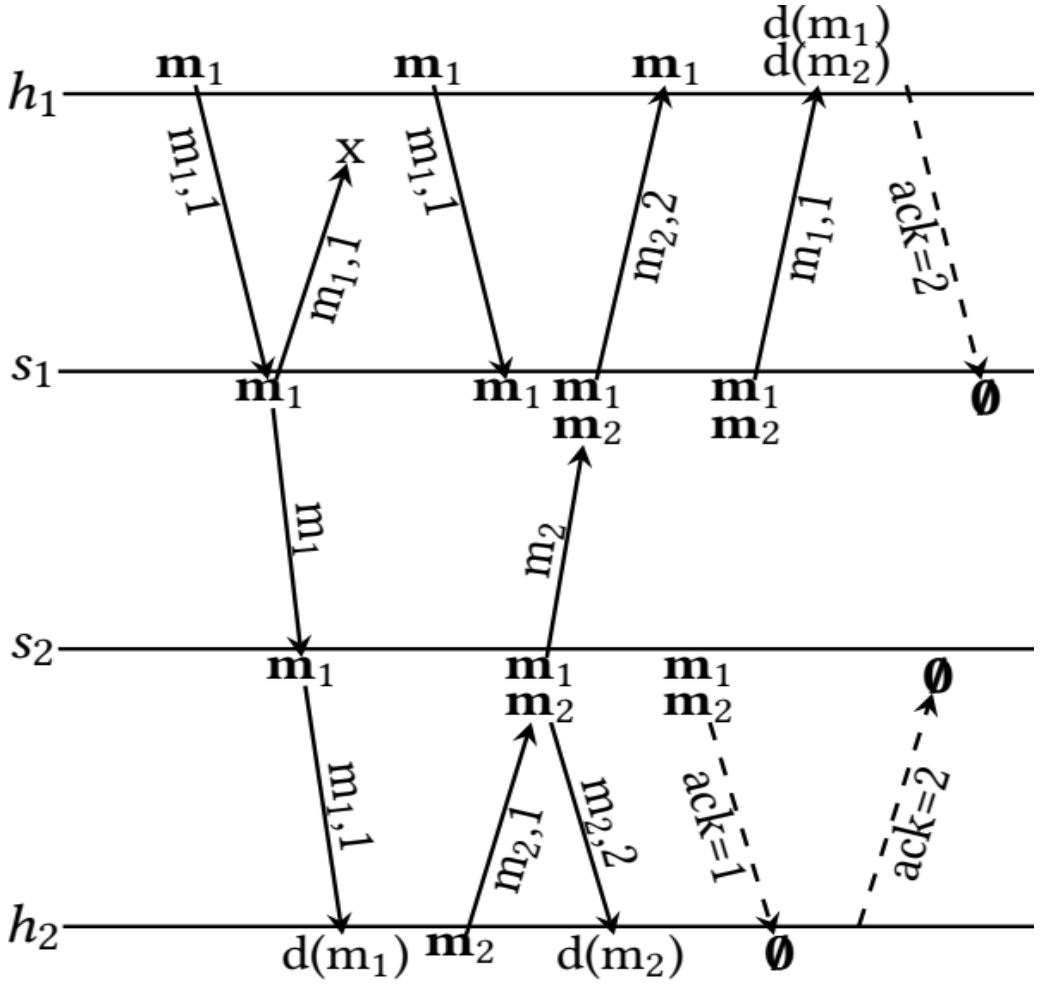
- Hosts capacity limitations: energy, computational, memory
- Stations hold most of the causal information
- Host dynamicity: free movement, leave/join network, failures
- Bandwidth and unreliability of the wireless network

Principles of the algorithm

Hosts are the source of application messages, stations ensure that all hosts deliver them causally

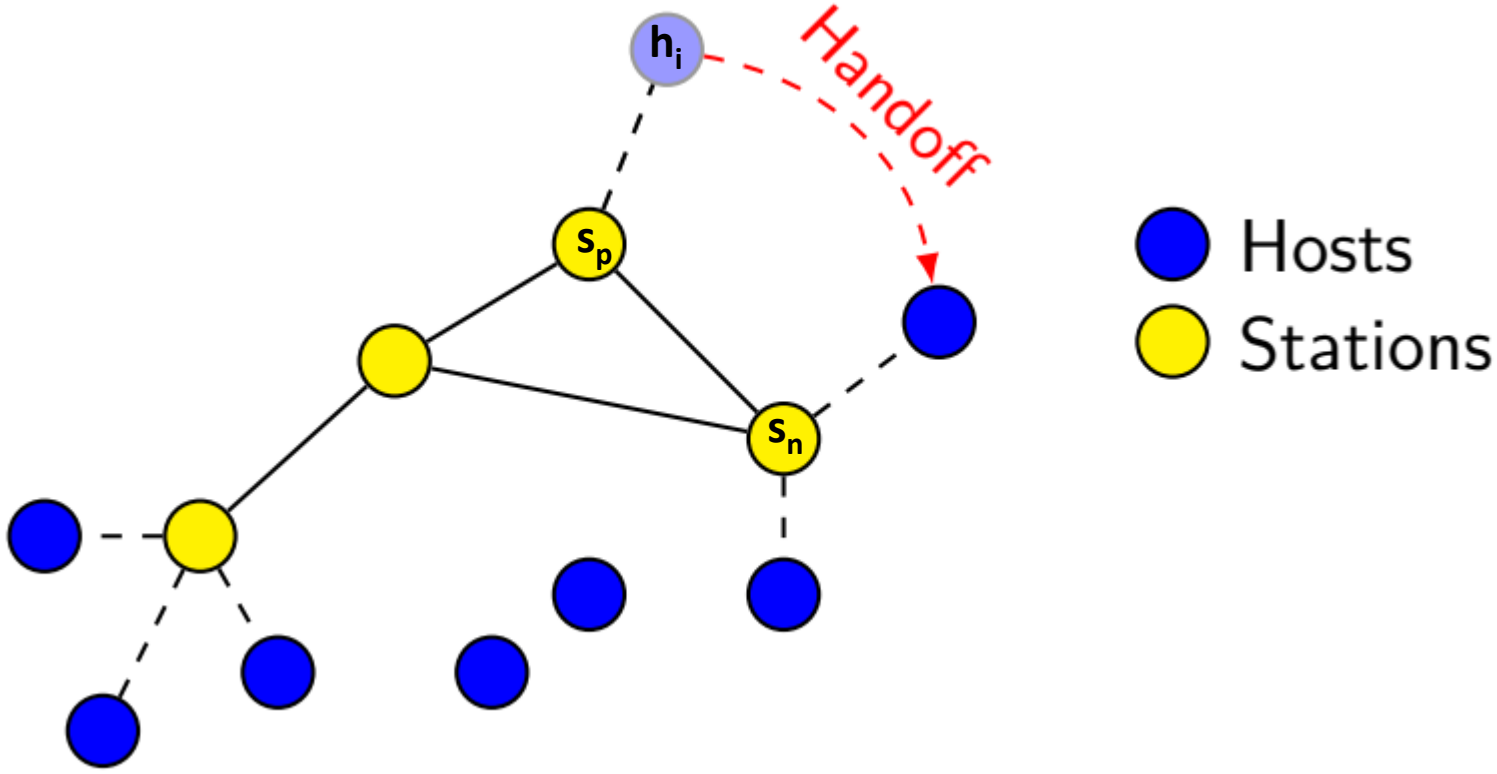
- Each *Host* maintains the sequence number of the next expected message.
- Each *Station* assigns sequence numbers to order messages inside its cells and retransmits messages on wireless and wire (FIFO) channels.
- Inside cells, ack included sequence number are periodically sent.
- A *station* discards a message once all its local hosts acknowledge it

Principles: information dissemination



m1 → m2

Mobility: Handoff

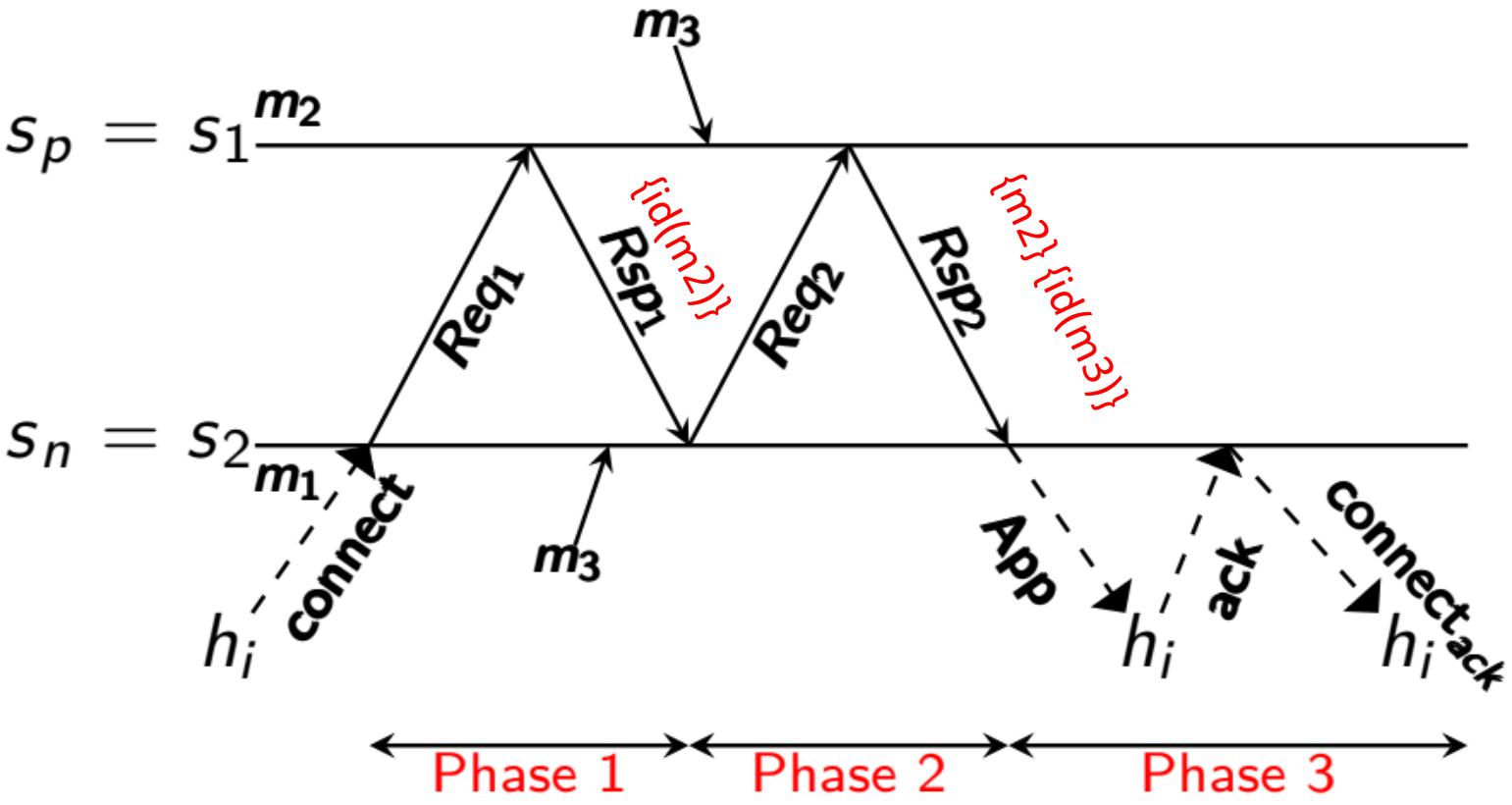


Handoff

- Phase 1: detection of discarded messages not delivered by h_i.
- Phase 2: detection of messages not delivered by h_i among messages that s_n caches.
- Phase 3: initialization of the connection between s_n and h_i.

Handoff exemple

- Initially : h_i delivered m_1, s_p has discarded m_1, s_n discarded m_2
- Both stations receive m_3 during the handoff



Performance evaluation

- Simulations implemented on **OMNeT++/INET**
  - Host mobility
  - Interferences, simulates network layers
  - Host failures

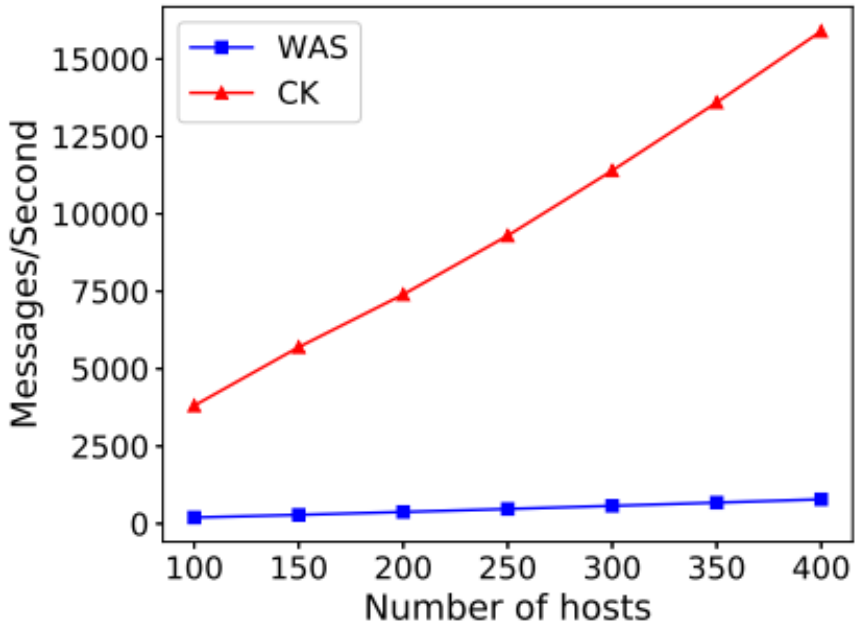
- Each host broadcasts application messages following a Poisson distribution.

- Hosts move in a straight line with a speed of 5km/h and change direction every 5 seconds

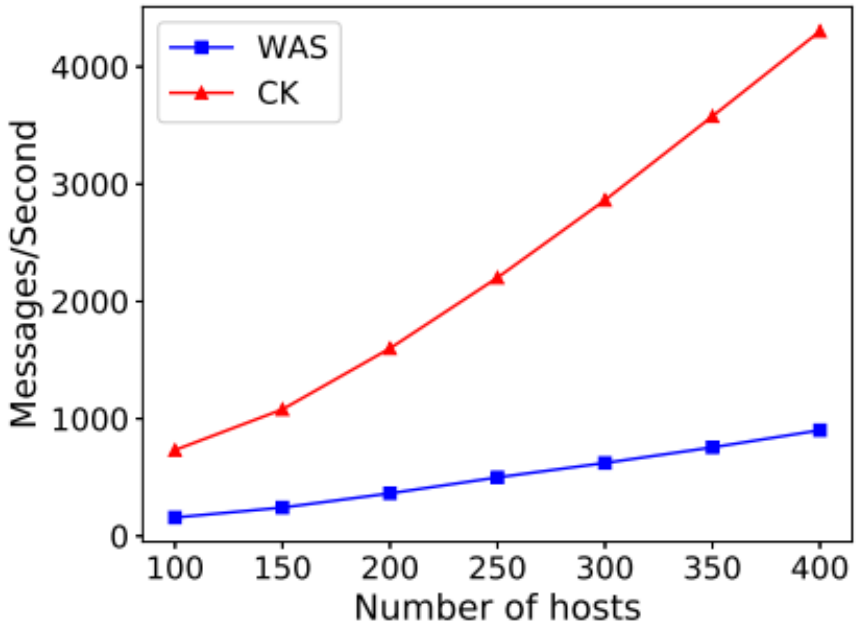
- Comparison with Chandra -Kshemkalyani (CK): a causal multicast algorithm for mobile network with a centralized discard mechanism (end-to-end ack).

Number of messages sent

10 stations

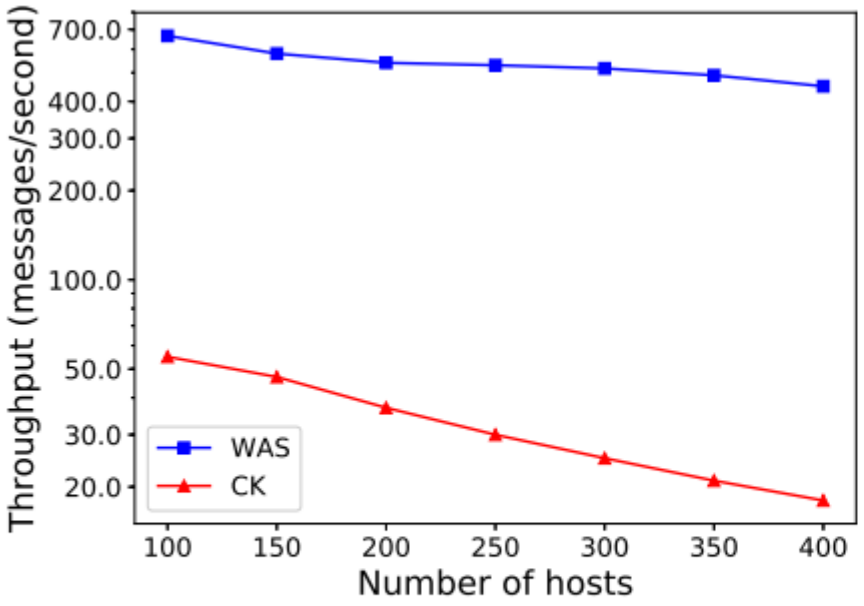


Messages/s on the wireless network

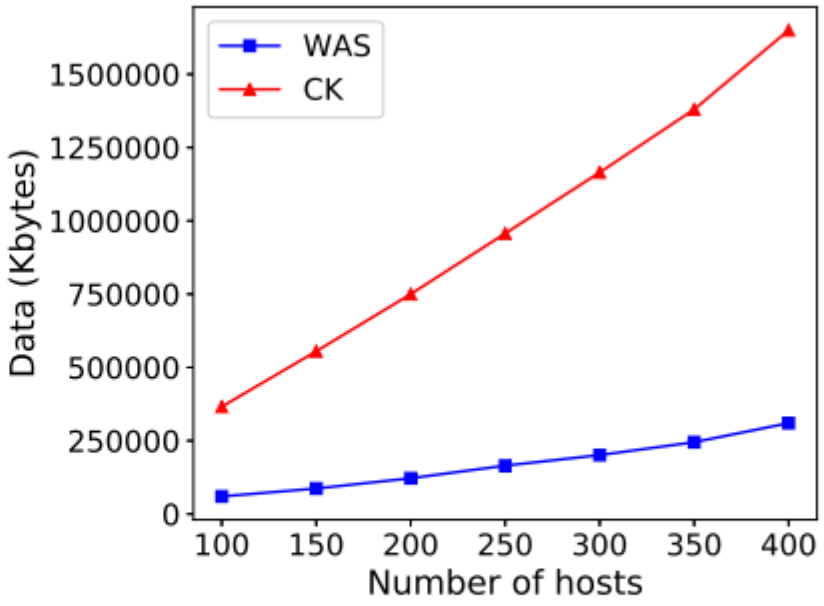


Messages/s on the wired network

Throughput and transmited data



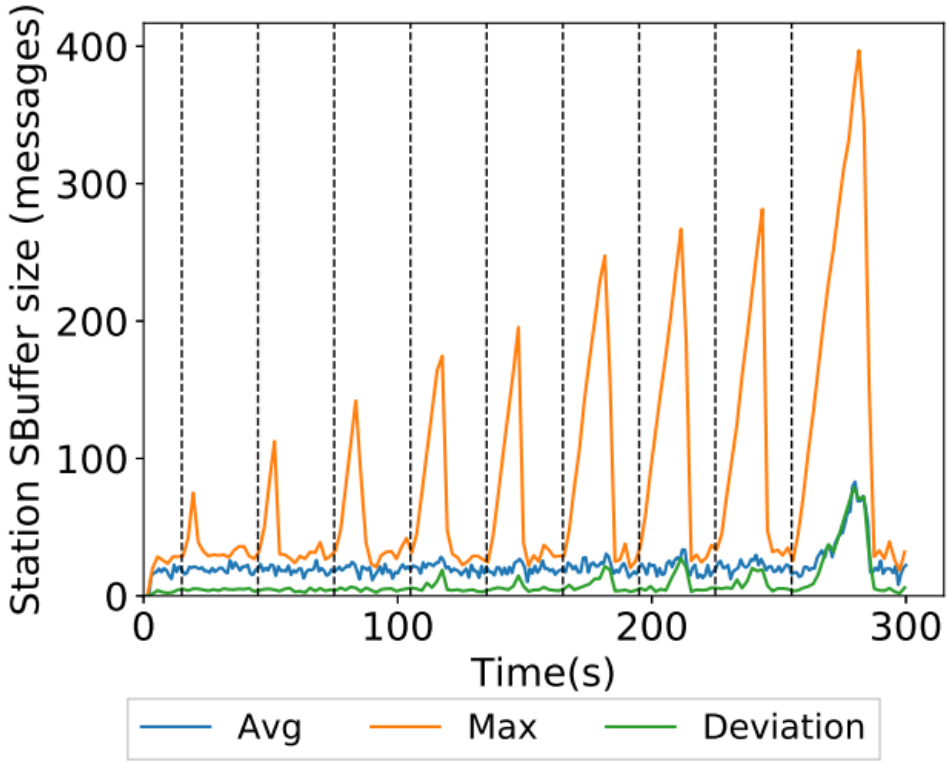
Throughput



Transmited data (wired and wireless network)

Failure injection ：Number of buffered messages at stations

- First host fails at t=10s and lasts 5s, then each 30 seconds another host fails, and the fault duration increases by 2 seconds at each failure



Conclusions

- A causal broadcast algorithm for mobile networks that:
  - Takes into account the energy, memory and computational limitations of hosts
  - Handles host failures
    Makes no assumption on host connection success
    Implements a decentralized deletion of obsolete messages
- The performance evaluation shows that, compared to existing solutions, the presented algorithm:
  - Sends much fewer messages on the wired and wireless network
  - Caches much fewer messages on stations
  - Sends much fewer data and has a much higher throughput

Ongoing work

- Tolerating failures of stations