Design and development of embedded systems for the Internet of Things (IoT)

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W • SENSE
INTEGRATED CABLELESS SOLUTIONS

The Collection Tree Protocol

CTP

Omprakash Gnawali, Rodrigo Fonseca, Kyle Jamieson, David Moss, and Philip Levis

Collection Tree Protocol

In Proceedings of SenSys'09, November 2009

Collection

- In a WSN the sensed data are collected by a small number of base stations, called sinks.
- Nodes don't need routes towards all the other network nodes.
  - Just to one sink (anycast communication).
- The routing protocols designed for this problem are called Collection protocols.

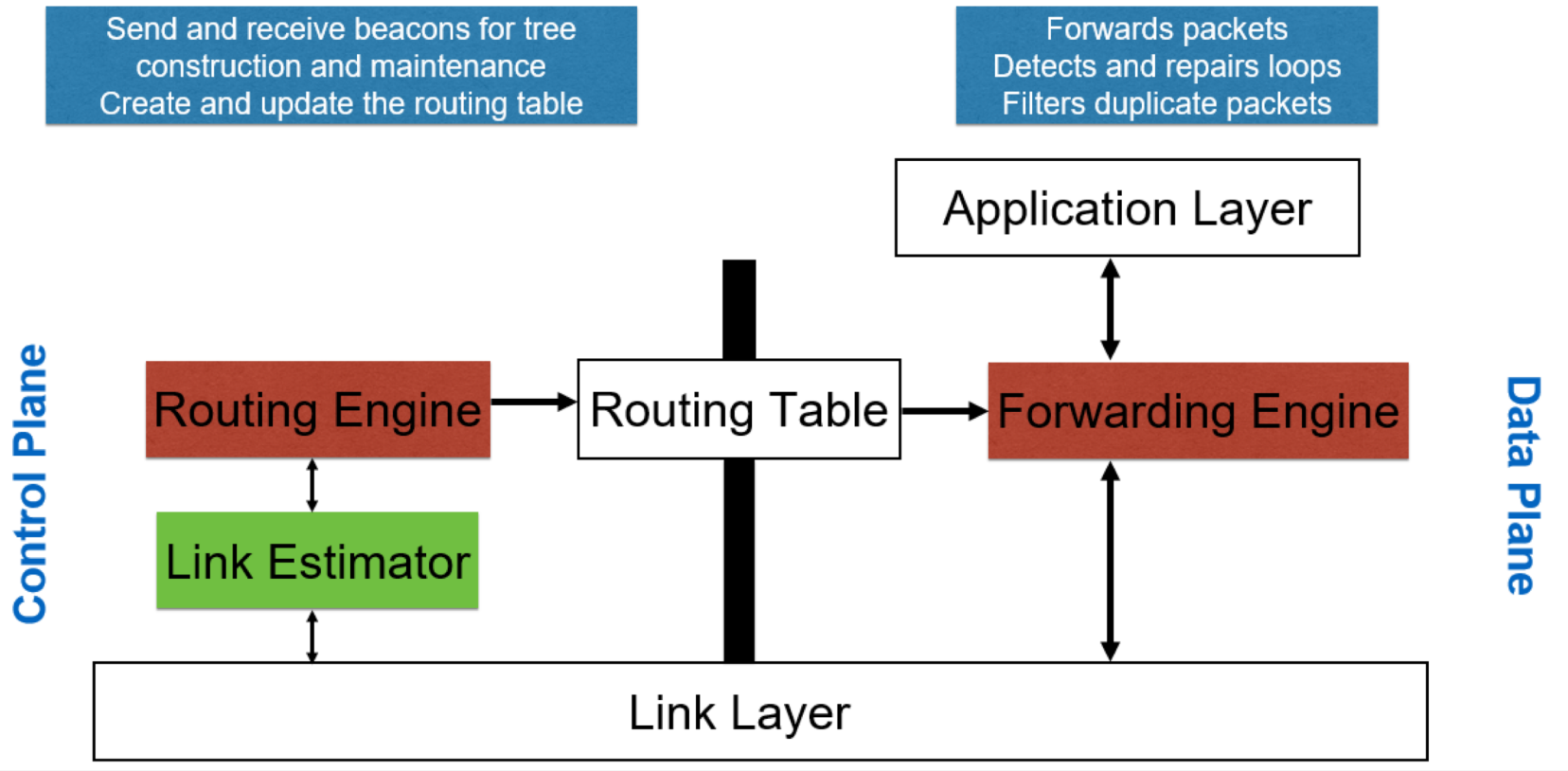
The Collection Tree Protocol (CTP)

- The Collection Tree Protocol is widely considered as the main routing protocol for data collection.
- It builds and maintains one or more routing trees, each one rooted in a sink.
- Every node “belongs” to a routing tree and select one of its neighbors as its parent.
  - Parents handle packets received from children nodes and further forward them towards the sink.

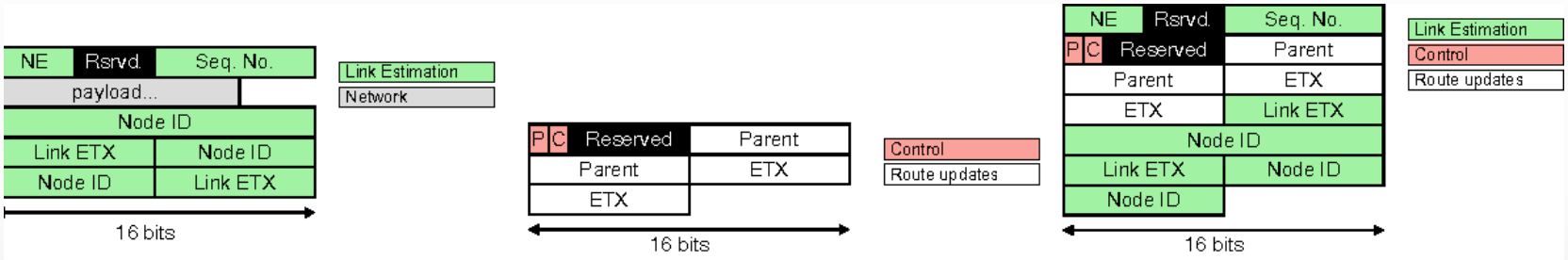
The Collection Tree Protocol (CTP)

- CTP is a distance vector protocol
- The metric is the Expected number of transmissions to reach the sink (ETX)
- The ETX of a node depends on:
  - Distance in hops from the sink
  - Quality of the communication links

CTP - Architecture



CTP: packet frames



(a) Link estimation frame (b) Routing frame (c) Complete routing frame

Figure 6. CTP routing frame format

CTP: Parent selection

- Every node needs to assess the quality of the communication links with its neighbors (ETX1-hop).
  - Outgoing link: percentage of acknowledged data packets
  - Ingoing link: percentage of beacon received by the neighbor.
- The ETX via a given neighbor is the sum of ETX1-hop and of the ETX announced by the neighbor with its beacons.
  - The neighbor with the minimum sum is chosen to be the parent.

CTP: Datapath validation

- Datapath validation is how CTP tries to fix routing inconsistencies.
- The next hop should be closer to the sink.
  - The ETX should decrease.
- Because of stale routing information, it can happen that a node sends a packet to a neighbor with a higher ETX.

CTP: Datapath validation

- Every data packet contains the transmitter's ETX.
- When a node receives a packet, it compares the transmitter's ETX with its own.
- If it is not greater than the receiver's ETX:
  - the receiver forwards the packet (to check if there are other inconsistencies)
  - the receiver increase the beacon transmission rate (trying to send updated information to neighbors with stale routes).

CTP: adaptive beaconing

- It is how CTP manage the beacon transmission interval.
- When the topology is stable sending beacon at a high rate is a waste of energy.
  - We can increase the interval.
- It extends the Trickle Algorithm:
  - Start with a small interval: $t_{min.}$
  - Double the interval up to $t_{max.}$
  - Reset to t_{min} when inconsistency is detected.

The Flooding Time Synchronization Protocol

FTSP

M. Maroti, B. Kusy, G. Simon, A. Ledeczi
SenSys 2004

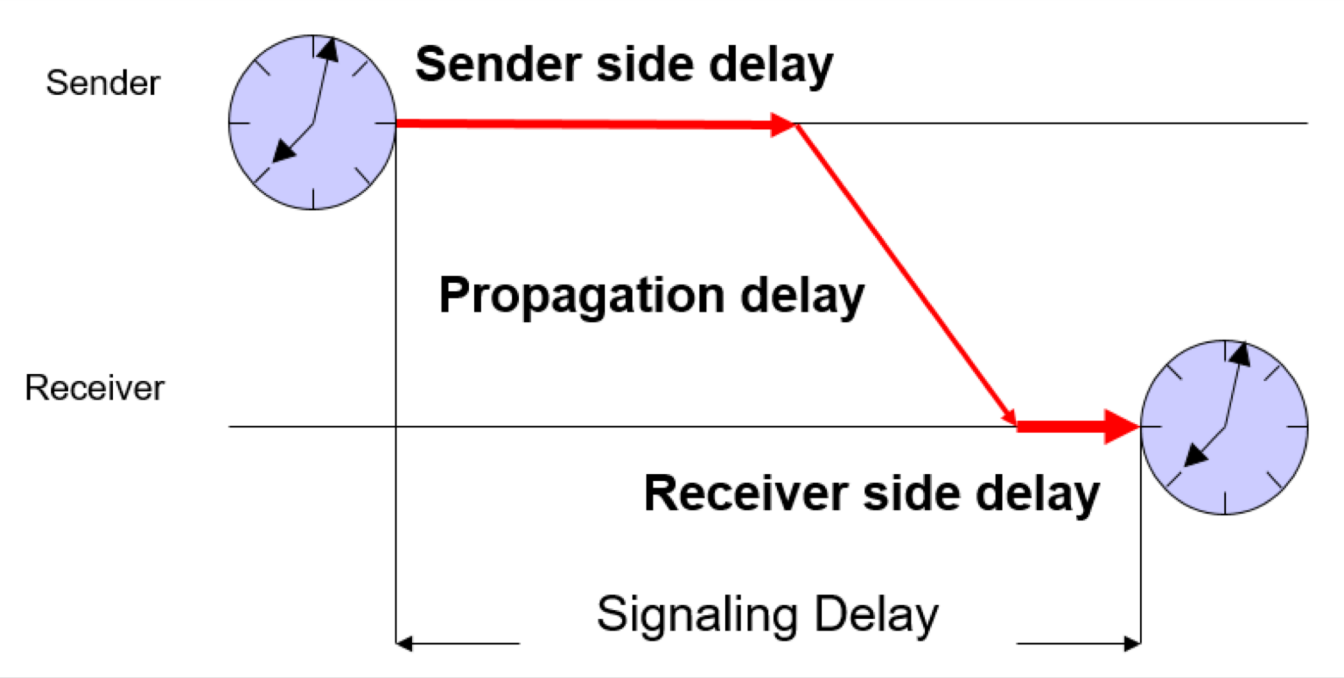
Time Synchronization in Sensor Networks

How is time synchronization in sensor networks different from the traditional networks?

- Energy Utilization
- Single hop vs. multi hop
- Infrastructure-Supported vs. Ad-hoc
- Static topology vs. Dynamic Topology
- Connected vs. Disconnected
- Dynamic time sync. requirements, depending on the application

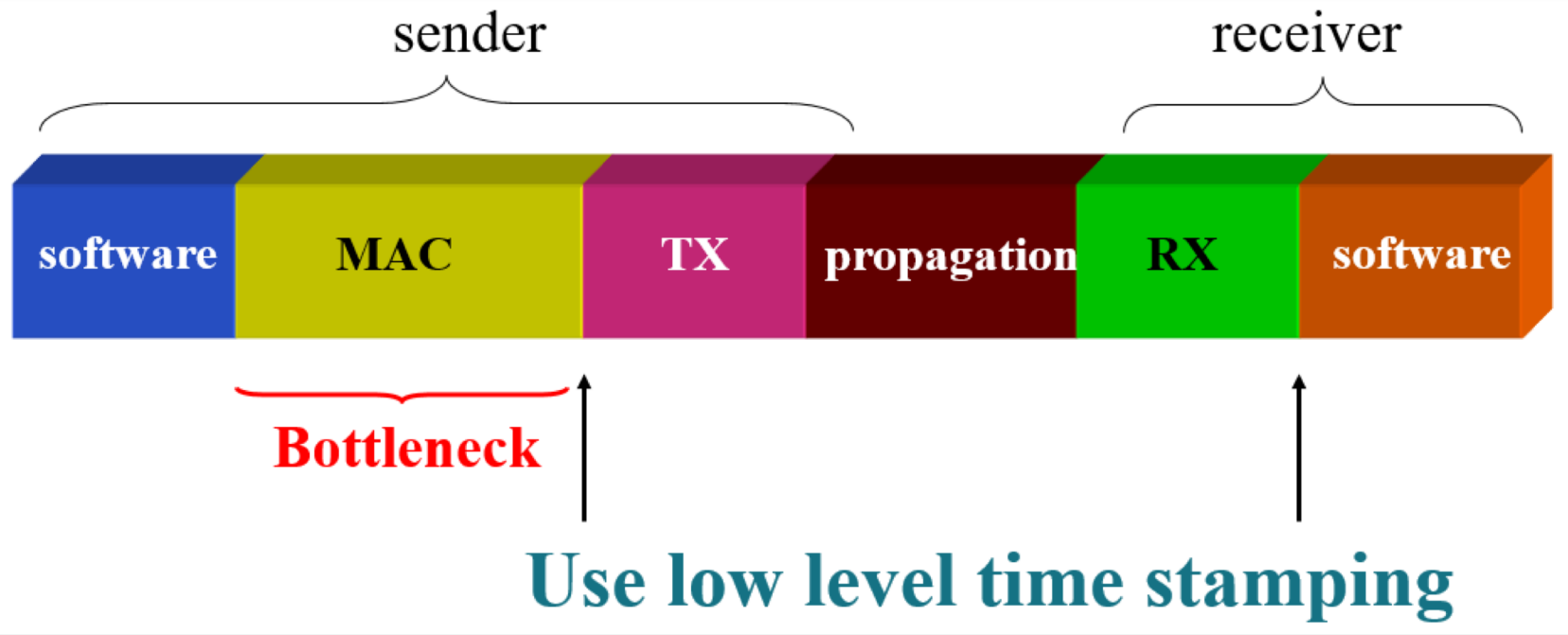
FTSP - Deal with Skew

- Receiver Time = Sender Time + Signaling Delay
- Challenging issue: estimate signaling delay!!!

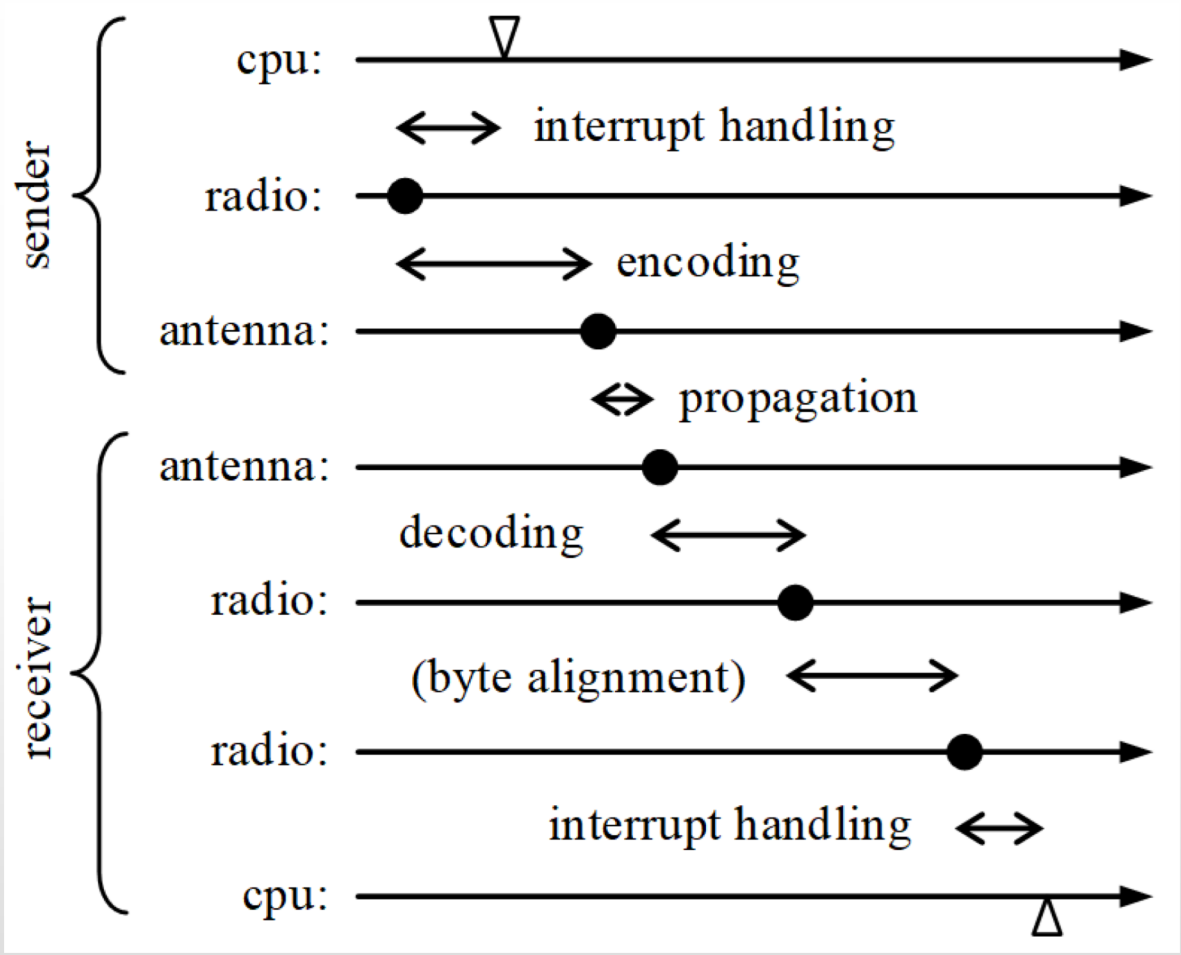


FTSP - Delays

All delays are variable

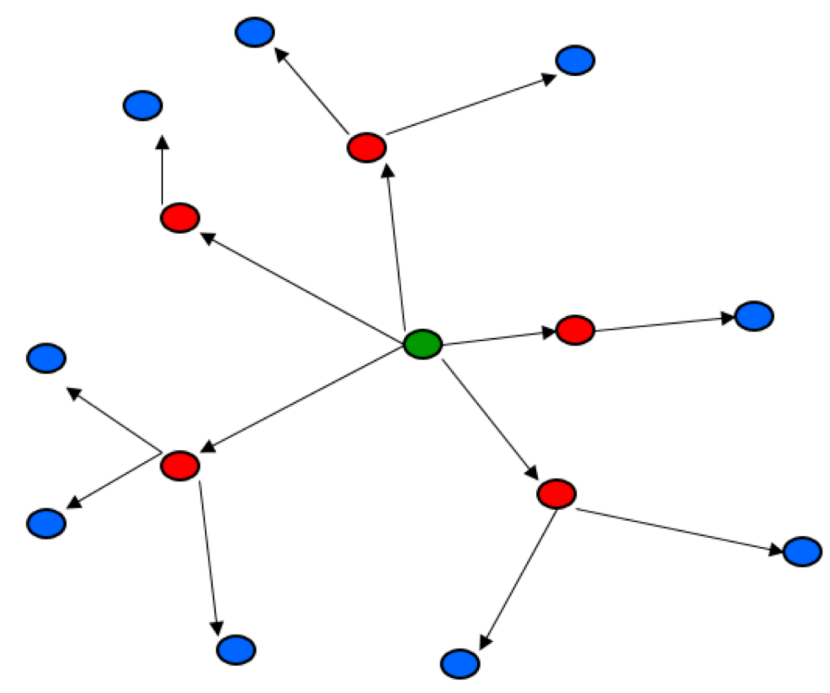


FTSP - Delays in TX and RX

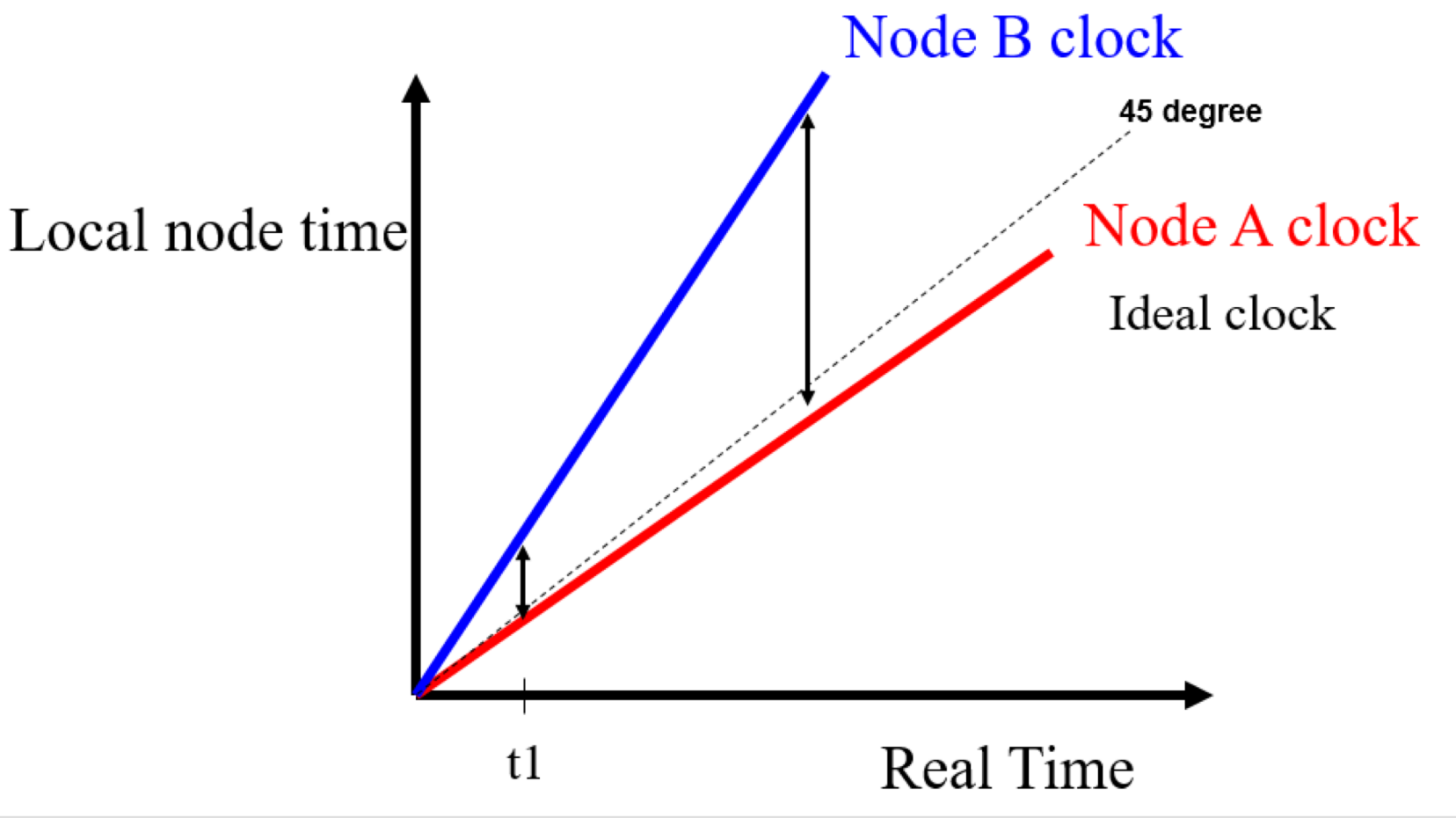


FTSP - Flooding

Use periodic flooding to provide robustness



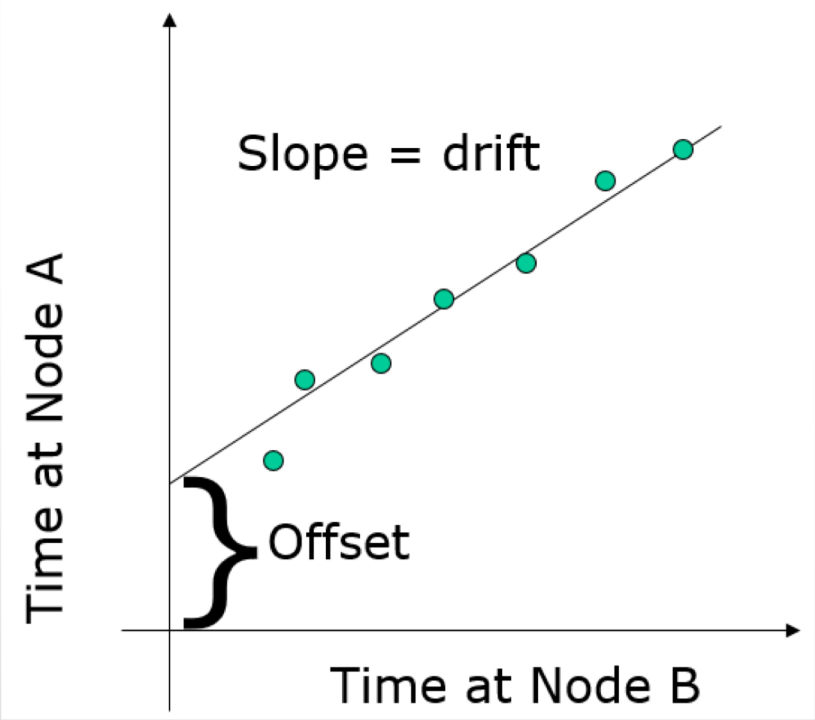
FTSP - Drift


Node B clock
45 degree
Local node time
Node A clock
Ideal clock
t1
Real Time

FTSP - Drift

Receiver gets the multiple time stamps (Ta, Tb)

- Uses this to update the estimate on the clock drift



FTSP - Analysis

- PROs
  - MAC layer delay are removed by low-level time-stamping
  - Robust
  - Clock Drift through linear regression
  - Support multi-hop time synchronization

- CONs
  - Relatively high cost in flooding
  - Special timestamp message needed