SiConnect Proposal for IEEE P1901 Co-Existence Cluster

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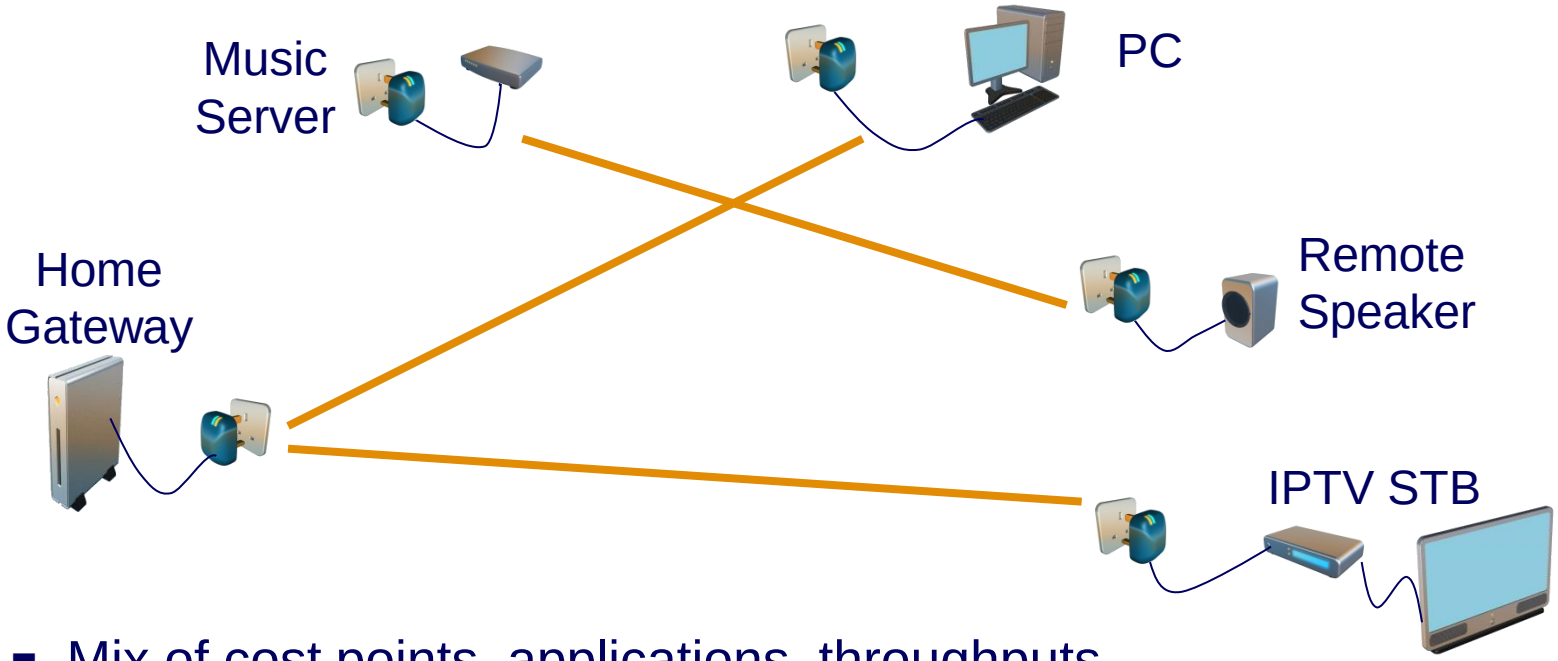
Contents

- Co-Existence and QoS Needs
- Overview of CX Proposal
- Protocol Detail
- QoS Priority
- Hidden Node Support
- Access Network Support

Key Features

- Co-existence mechanism for the QoS needs of applications running over disparate in-home powerline technologies
- Simple and Lightweight – No message exchange between nodes
- No arbitrary limits on numbers of nodes/networks/technologies
- Distributed Sub-MAC protocol – all nodes can arbitrate for the media
- Deep QoS support
- Maximises bandwidth utilisation
- Supports co-existence with slow modems without impairing performance of P1901 modems
- PHY-agnostic
- Mature approach, proven over past 8 years at SiConnect
- Partial Proposal

The Co-Existence Challenge

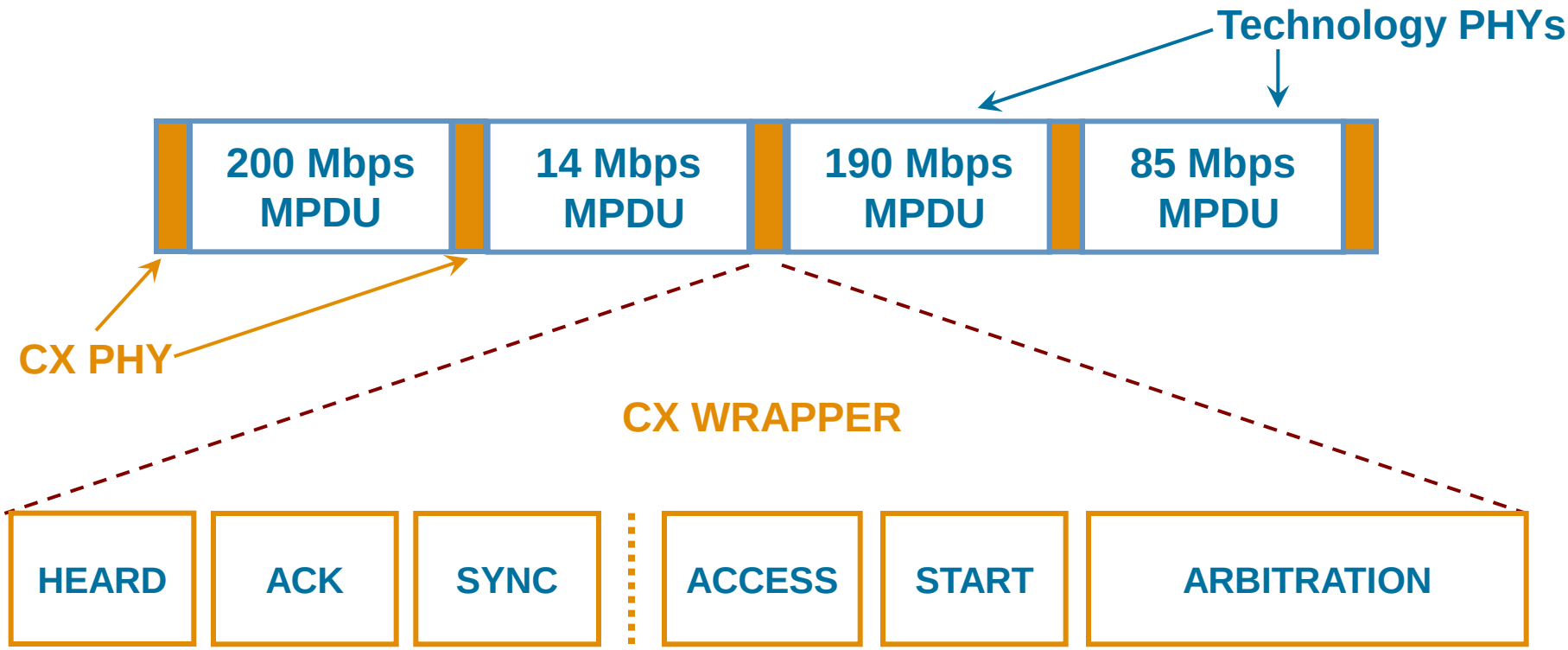


- Mix of cost points, applications, throughputs
- Constraints on available bandwidth
- Even distribution of network resources between technologies
  vs
  Sharing resources fairly between applications according to need
- QoS CX would be a pre-cursor to an Interop spec that supported QoS

QoS in a Bandwidth-Constrained Network

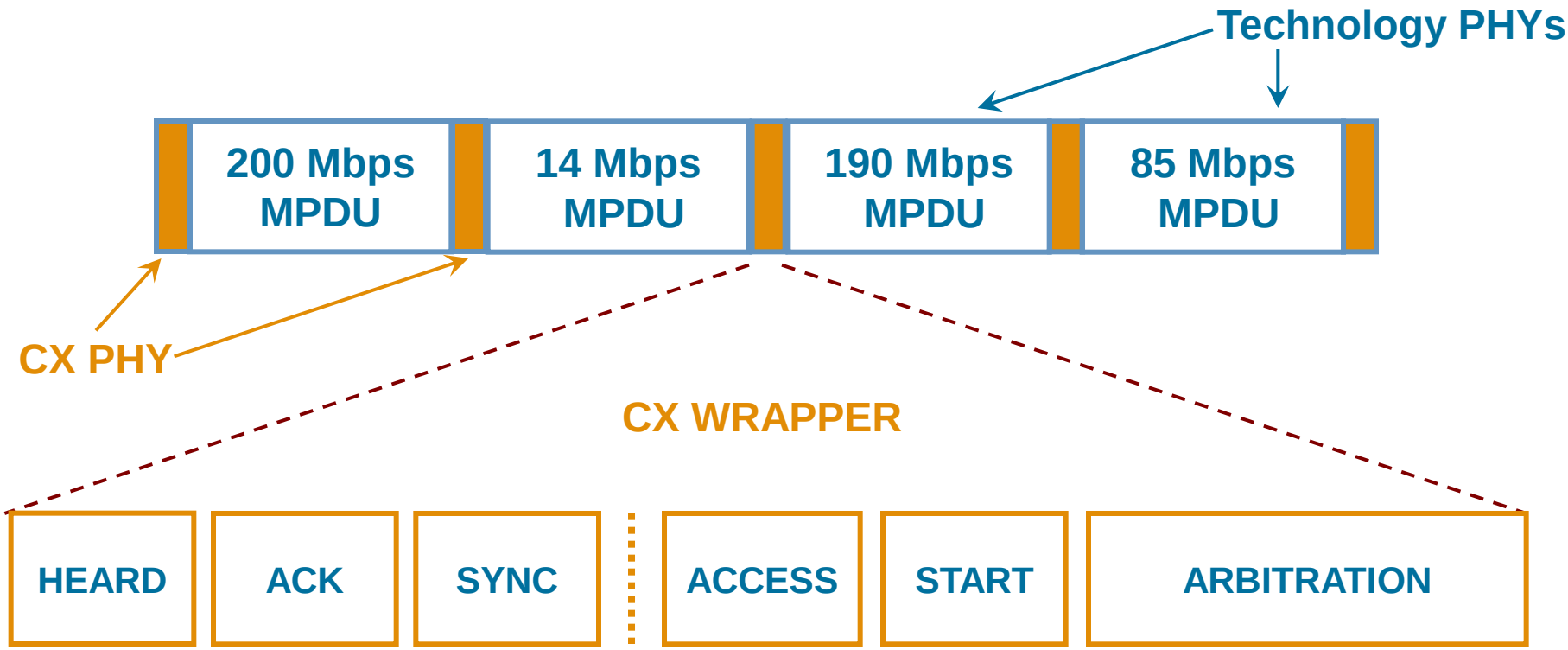
- QoS is not:
  - Bandwidth allocation
  - Equal shares of time on the wire
- QoS is about:
  - Bandwidth prioritisation
  - Managed Latency/Jitter
  - Deterministic access times
  - Equal allocations of time on wire (fair shares) for same class of service
  - Fine-grain management of resources
  - Differentiating between managed and unmanaged services

Thumbnail of SiConnect Partial Proposal -1



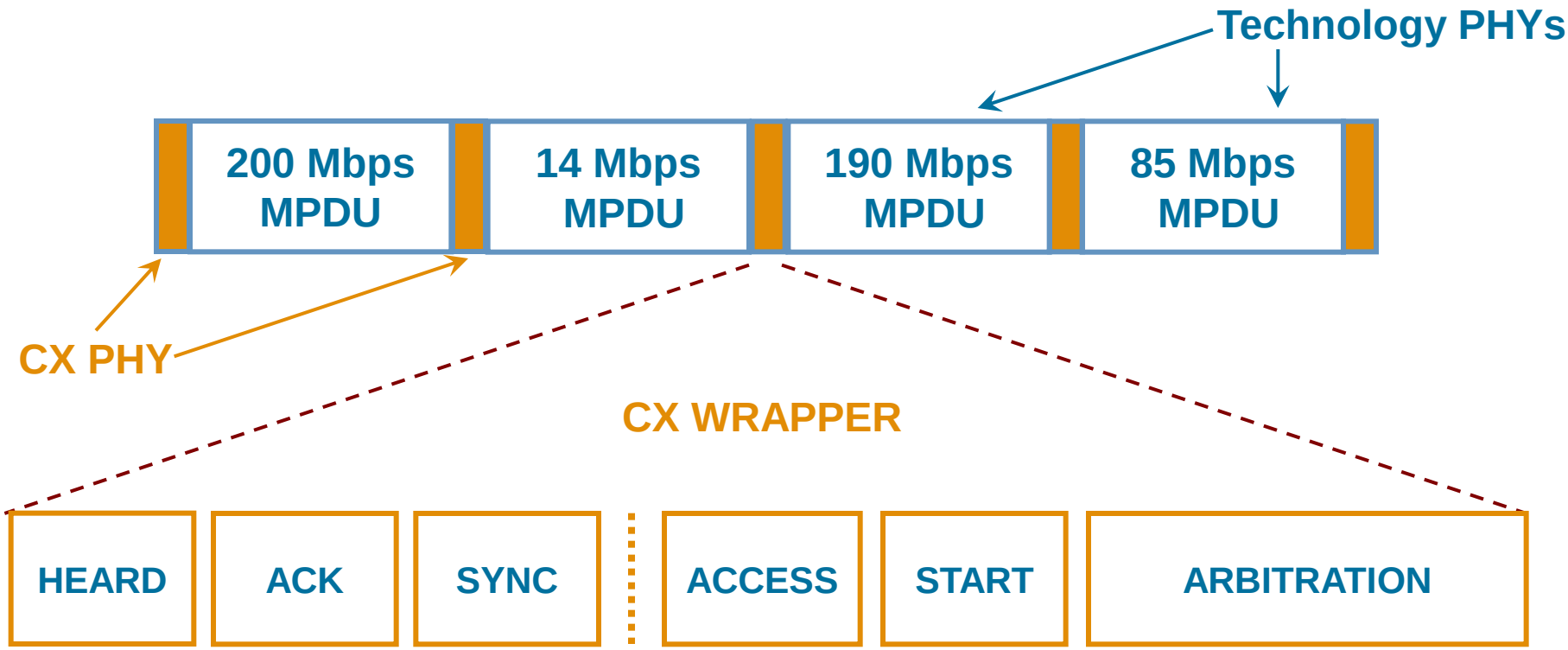
- Fully distributed arbitration protocol
- Access to the in-home powerline is achieved by bit-wise arbitration
  - QoS is built-in at the CX “Sub-MAC” layer by mapping service priorities onto arbitration bits

Thumbnail of SiConnect Partial Proposal -2



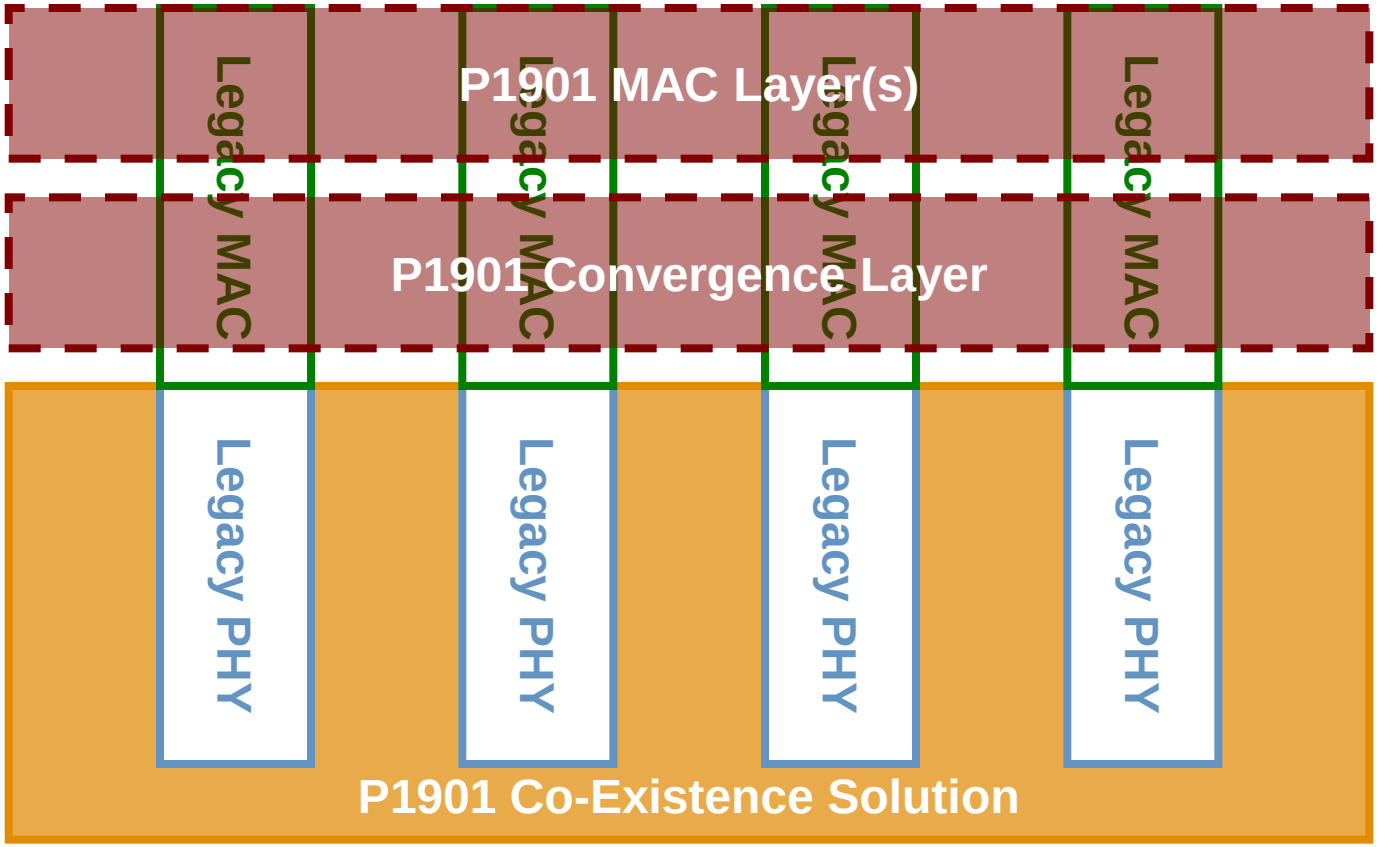
- No external time reference needed
  - Synchronisation achieved with SYNC and HEARD indications
  - HEARD indications allow hidden nodes to synchronise with the network

Thumbnail of SiConnect Partial Proposal -3

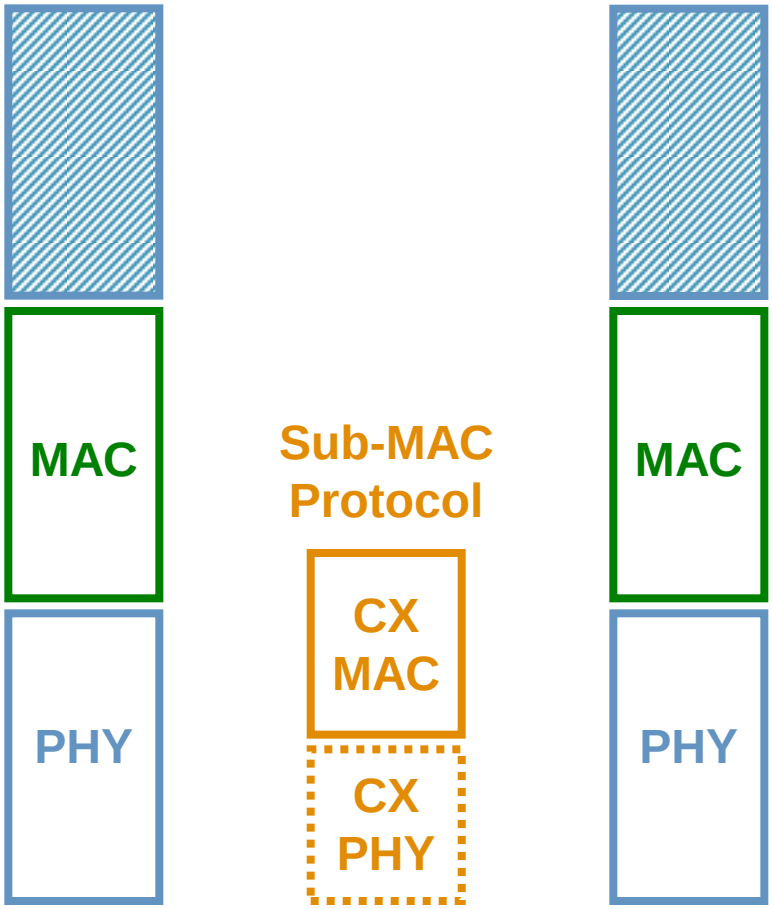


- Variable length MPDUs to maximise utilisation of available bandwidth
- Regular access to the medium guaranteed for an Access Network by ensuring arbitration success in alternate contention periods

Co-Existence in a Pre-Interop Powerline

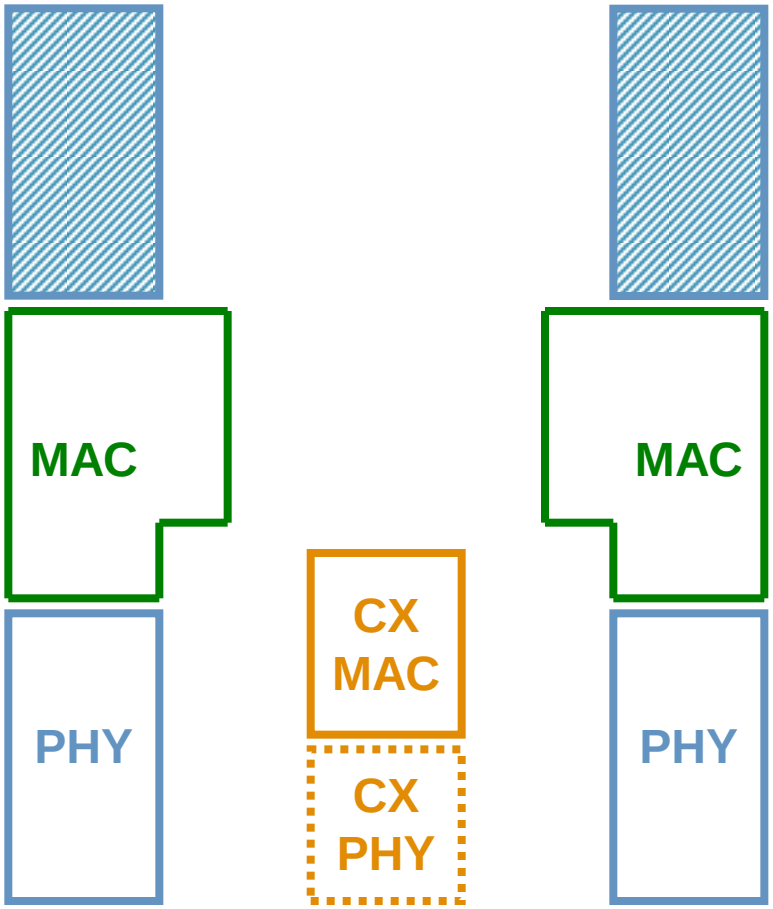


Lightweight CX Solution



- Lightweight CX PHY
  - Cost-effective to add to existing solution
- PHY-agnostic CX MAC
- Fully distributed CX MAC architecture
  - Arbitrates between all nodes seeking access to medium
  - Implements fine-grain QoS
- Data-path MAC/PHY operate as before
  - eg Master/Slave or Peer-to-Peer architectures unaffected

Lightweight CX Solution



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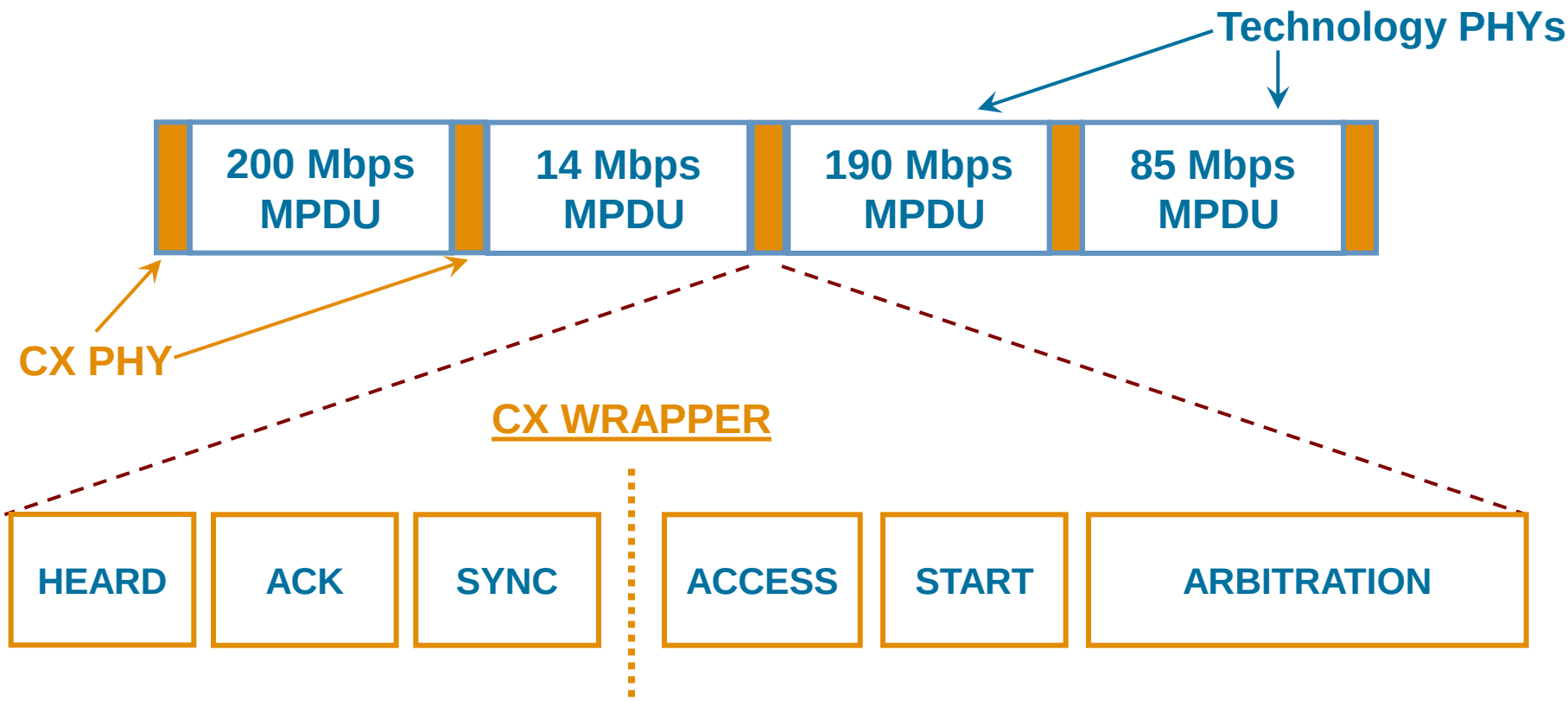
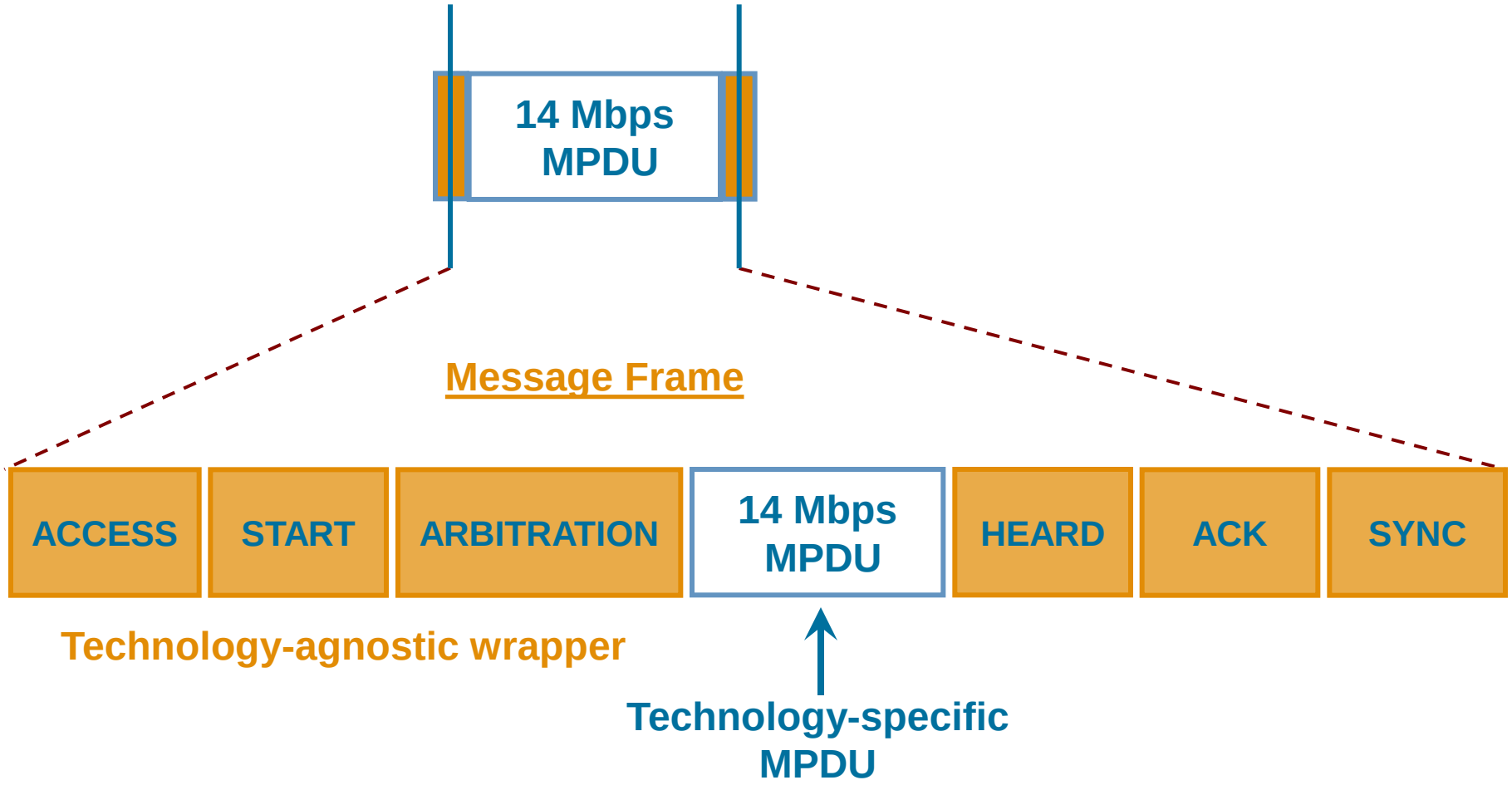
Use of the Partial Proposal

- At the core of the proposal is the use of Non-Destructive Bit-Wise Arbitration to deliver QoS
- Other proposed features in the proposal reflect experience of a powerline implementation
  - These features work together as a whole, but…
  - Alternative feature combinations should be constructed to meet P1901 needs
- Could easily add:
  - Beaconing
  - Zero-crossing detection
- Must add:
  - CX PHY

Co-Existence Wrapper



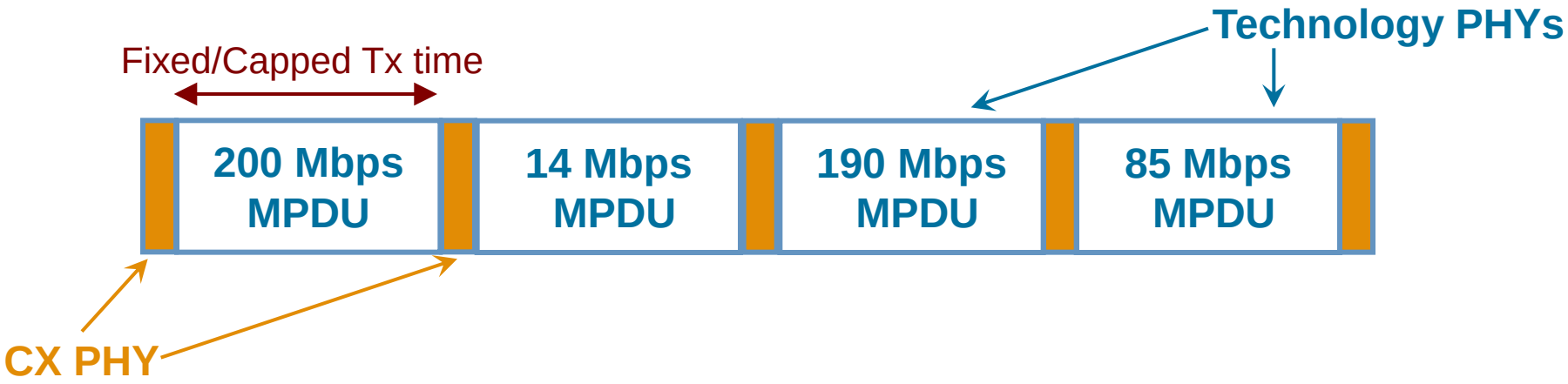
Message Frame



Bitwise Arbitration Delivers Deep QoS

- At end of message frame, all nodes wishing to transmit start to arbitrate based on a priority field incorporating application service priority
  - Arbitration resolves contention before collision occurs
- No collisions → No retries → Deterministic access times
- Capped time on wire for each packet
  + Prioritised/deterministic medium access =
  - Tightly bounded packet latency
  - Tight jitter
  - Deep QoS (4-bit QoS field = 16 service levels)
  - No bandwidth hogging
- Access Network has over-riding priority on alternate packets
  - Guarantees 50% of bandwidth to access network

CX Protocol Timings



- MPDU can be fixed time on wire
  - Potentially inefficient network utilisation, compatible with TDM technologies
- MPDU can have capped time on wire
  - Allows back-to-back variable-length MPDUs - maximal utilisation of time on wire by all technologies and applications
- CX wrapper fixed length of time
  - Depends on choice of PHY, correlator complexity, number of arbitration bits

Robustness and Reliability

- Requirements
  - Very high probability of detection
  - Very low probability of false detection
- Achieved through use of correlators
  - Cross-correlators
  - Auto-correlators
  - Combination of both
- Trade-off between robust/reliability and protocol overhead
  - P1901 decision

Non-Destructive Bitwise Arbitration

- Synchronisation
- Arbitration
- Access to Medium

1 – Synchronisation

- Network uses a SYNC heartbeat
  - The current Medium owner releases the Medium at the end of its technology specific MPDU with a SYNC indication
  - HEARD is transmitted by all Nodes that compute a valid MPDU CRC – using technology specific CRC/ARQ mechanism and regardless of Network Address
  - SYNC and HEARD have a fixed and known time offset from the START of FRAME Indication
  - Hidden Nodes that do not hear SYNC use the HEARD Indication and add the fixed offset to START of FRAME to maintain Network Synchronisation
  - Synchronisation does not need Mains Cycle synchronisation or Zero Crossing Detection but it can – if that is what P1901 require

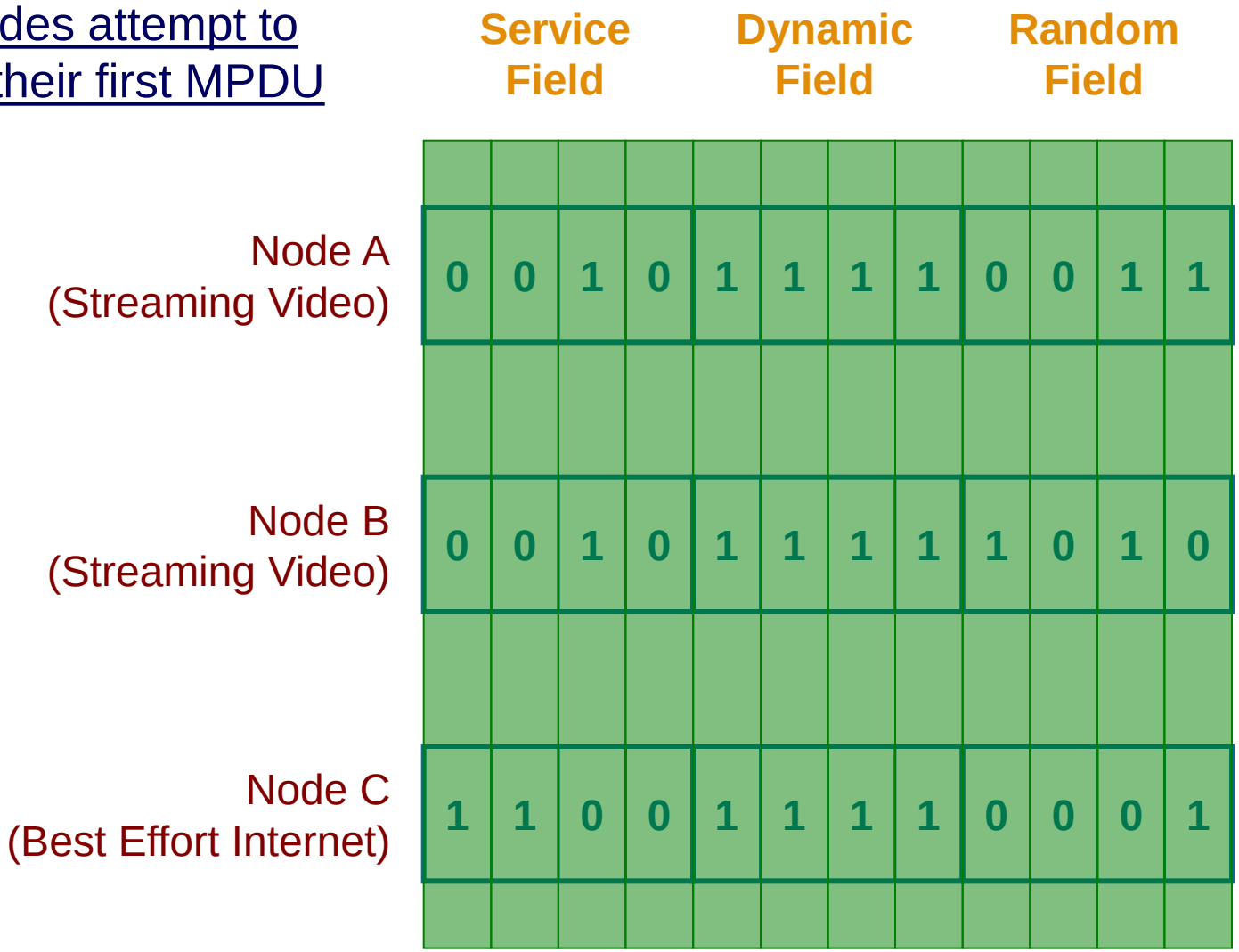
2 – Arbitration

- Non-Destructive Bitwise Arbitration
  - 0 (coherent energy on wire) wins over 1 (no energy)
  - Arbitration words placed on wire bit-by-bit
  - When one node's 1 loses to another node's 0, it drops out (and waits until next SYNC period to arbitrate again)
- Arbitration field consists of three parts

  - Service priority assigned by application
  - Dynamic arbitration implements round robin for equal service priorities during arbitration
  - Random priority avoids stand-offs

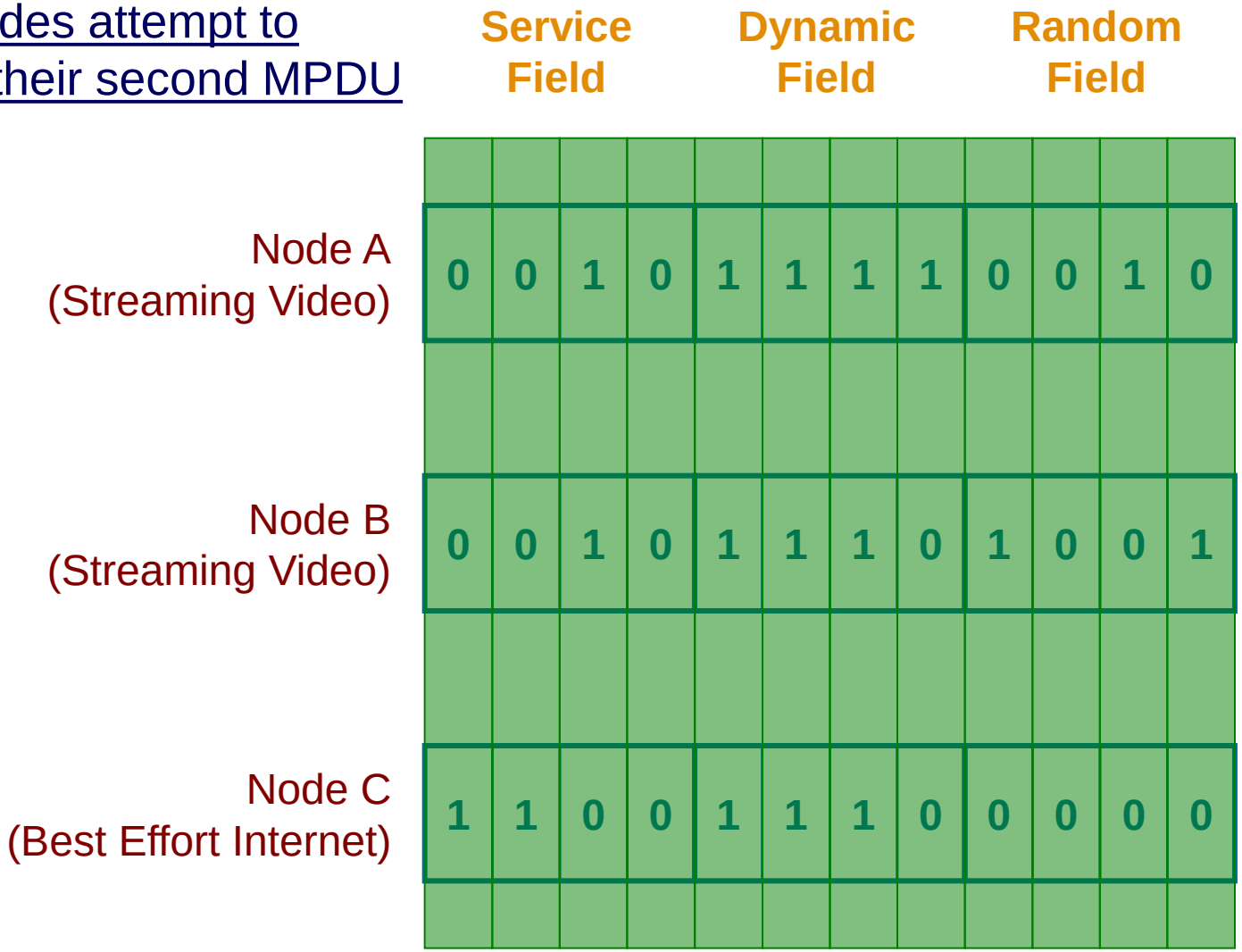
Bitwise Arbitration Example -1

Three nodes attempt to transmit their first MPDU



Bitwise Arbitration Example -2

Three nodes attempt to transmit their second MPDU

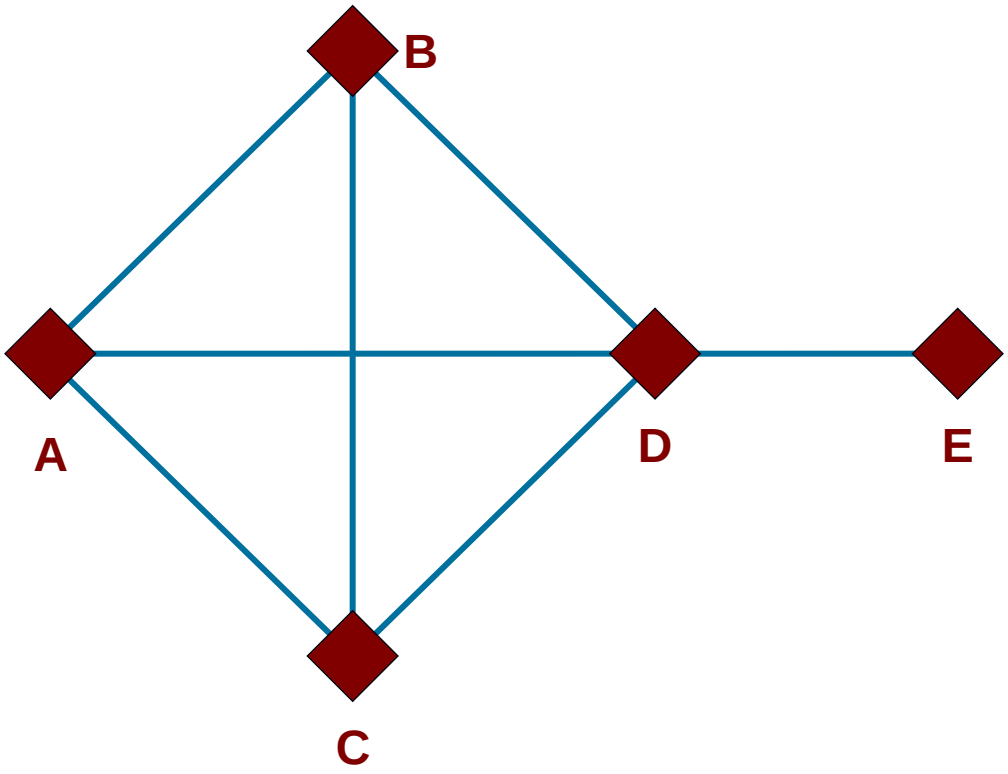


3 – Access to Medium

- SMA/CR – Synchronous Multiple Access/ Contention Resolution.
- Strictly speaking it is a Plesiocronous
  - Plesiochronous (pronounced plee-see-AH-krun-us, from Greek *plesos*, meaning close, and *chronos*, meaning time) is an adjective that describes operations that are almost, but not quite, in synchronization - in other words, almost synchronous. Time of flight is the variable.
- Access to the Medium is by using a class of protocol known as Contention Resolution.
  - Extensively used in the Automotive industry where it is known as CAN (Controller Area Network) and deployed in millions of cars
- Adapted for powerline by nSine in 2000
  - Improved over last 7 years to include Correlator detection rather than simple RSSI to differentiate in band noise from wanted signal and therefore significantly improve low probability of false detection

Hidden Node Management

- Hidden Nodes can be synchronised
  - No need to exclude them from the network



- E is a Hidden Node
- C transmits to B
- At end of Tx, all nodes that observed the Tx (A, B, D) send out a HEARD indication
- D's HEARD reaches E
- C sends SYNC indication
- E deaf to SYNC, but knows when it happens based on the timing of the HEARD indication

QoS Implementation

- 4-bit service priority
  - 16 levels of QoS supported (scope for 802.1D+)
- Deterministic access time onto medium
  - Underpins managed latency & jitter
- Application priority, rather than even share for each technology
- Equal service priorities treated on round robin basis
  - Best effort data could be crowded out in a loaded network
  - If desired, weighted round robin would ensure a share for best effort
  - P1901 to decide

Prioritised QoS Mappings

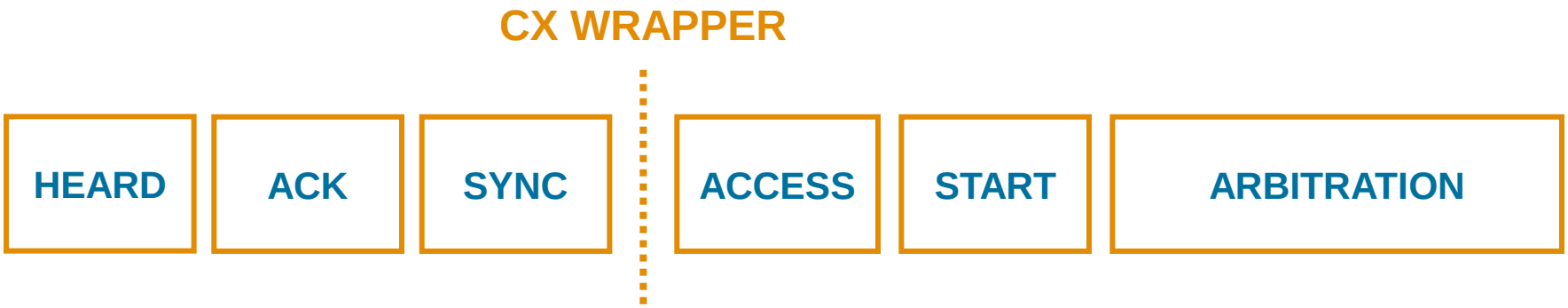
802.1D Traffic Class	User Priority	Service-Arbitration Mapping	
Background	1	14	1110
Spare	2	13	1101
Best Effort	0	12	1100
Excellent Effort	3	8	1000
Controlled Load	4	6	0110
Video < 100mS Latency	5	4	0100
Voice < 10mS Latency and Jitter	6	2	0010
Network Control	7	0	0000

Network Start-Up

- If network is quiet, no SYNC indication exists to allow transmit to begin
- Would-be transmitters (nodes with messages queued for sending) waits for max MPDU time, then sends SYNC indication
- Allows arbitration to begin if other transmitters were also waiting before transmitting

Access Network Co-Existence

- Co-Existence wrapper contains an “ACCESS” indication
- Access Network can assert the ACCESS indication in half of the arbitrations (ie alternate packets)
  - The ACCESS indication always wins in any arbitration
- The Access Network can gain up to half of the network time



Conclusion

- Partial Proposal that implements QoS Co-Existence
- Targeted at multi-application powerline environments
  - Multiple speeds
  - Different cost points
  - Cost of interoperability may not be appropriate
- Easy to implement as a Sub-MAC layer within existing powerline solutions
- Can be merged with any/all other CX proposal
  - Other features can be moulded around the Bitwise Arbitration mechanism

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