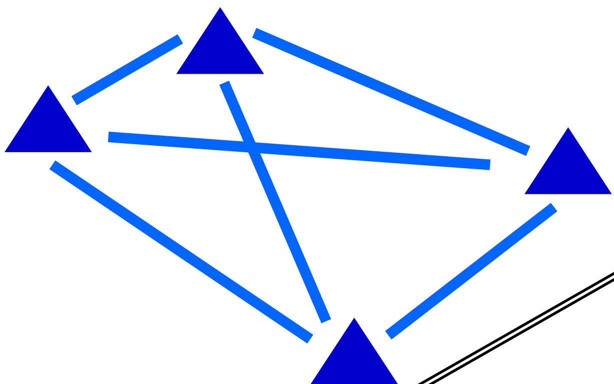
Ecma/TC48/2008/033
(Rev. 3 – 9 Oct. 2008)

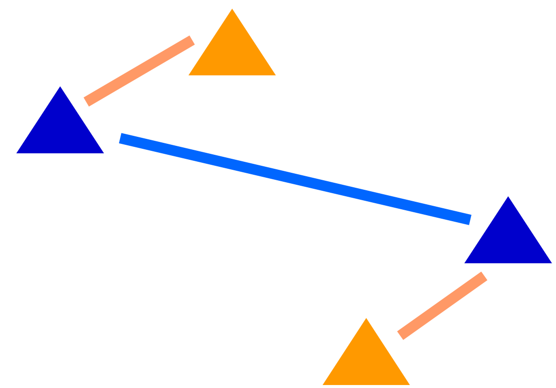
Ecma TC48 draft standard for high rate 60 GHz WPANs

October 2008

1.3 Heterogeneous networking

Homogeneous Networking
All device PHYs have the same capability





Heterogeneous Networking
Not all device PHYs have the same capability

TC48 60 GHz offers the only heterogeneous network solution that provides interoperability between all devices!

1.4 Device Types

Type A Device

- Services video and data over LOS/NLOS with Trainable Antennas
- Considered “high end” device
- Bandwidth efficient modulation
- Significant baseband DSP (equalization, FEC, etc.)

Type B Device

- Services video and data over LOS with Non-Trainable Antennas
- Considered “economy” device
- Minimal baseband DSP (no equalization, minimal FEC, etc.)

Type C Device

- Data only over LOS at <1 meter range
- Considered “bottom end” device
- Cheap PHY implementation
- Limited EIRP/range with Non-Trainable Antennas

1.2 Applications

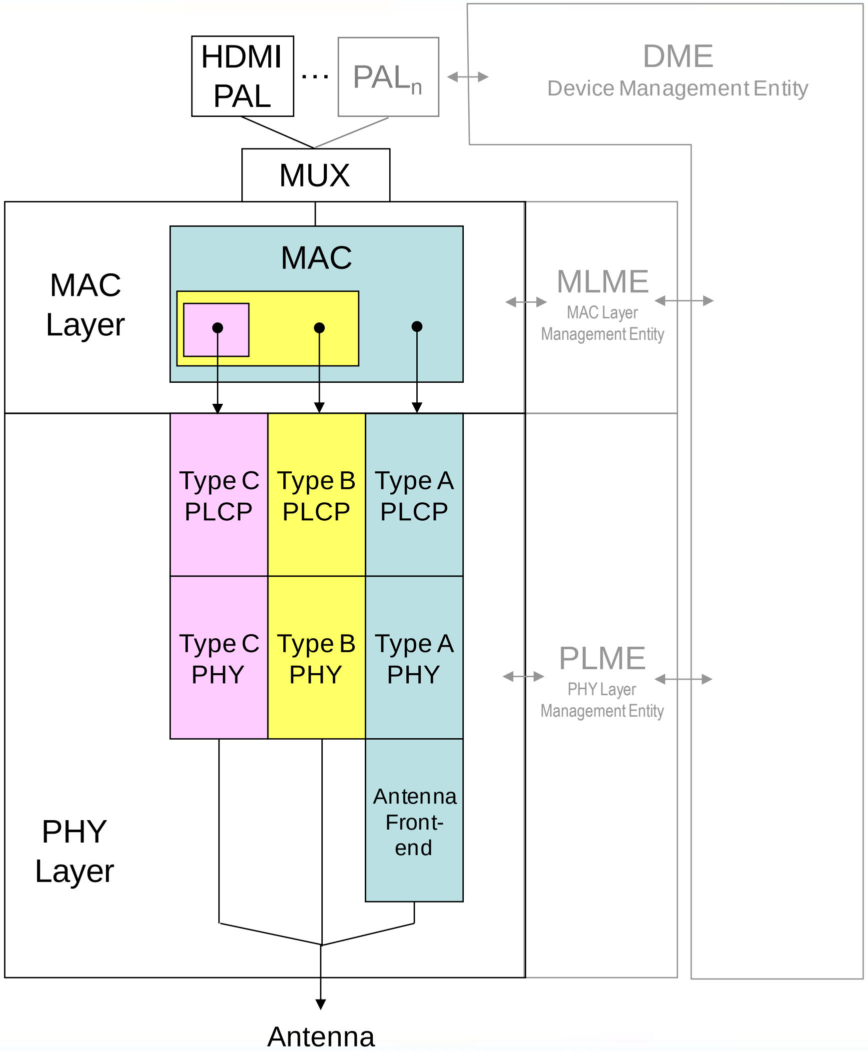
1. Wireless Uncompressed / Lightly Compressed Video
   - 10 meters
   - 1 to 5 Gbps
   - Obscured LOS / Strong NLOS Reflection

2. Wireless Docking Station
   - 1 meter
   - 1 to 5 Gbps
   - NLOS

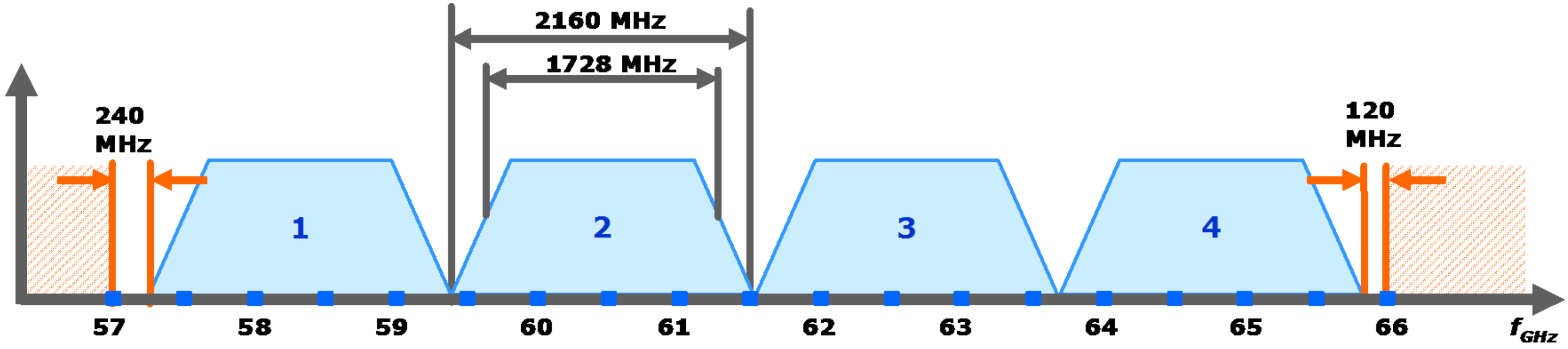
3. Large File Download
   - >500 Mbps
   - 10 meters
   - LOS / NLOS

4. Short Range Sync&Go
   - 0.5 meter
   - LOS
   - >500 Mbps

1.5 Protocol Structure



2.1 Frequency Plan



PHY Layer Device Types

Type A Common Mode SCBT	Type B Common Mode DBPSK	Type C Common Mode OOK
Mandatory Modes • SCBT • DBPSK • OOK Optional Modes • OFDM • UEP • DQPSK • 4ASK	Mandatory Modes • DBPSK • OOK Optional Modes • DQPSK • UEP • Dual AMI • 4ASK	Mandatory Modes • OOK Optional Modes • 4ASK

	Beacon		DRP
Type A:	SCBT		SCBT / OFDM / DBPSK / DQPSK / OOK / UEP /4ASK
Type B:	DBPSK	SCBT*	DBPSK / DQPSK / UEP / Dual AMI / OOK / 4ASK
Type C:	No Beacon		OOK /4ASK

* Transmit Only

2.2 Type A PHY

The Type A PHY includes two general transmission schemes, namely Single Carrier Block Transmission (SCBT), also known as Single Carrier with Cyclic Prefix, and Orthogonal Frequency Division Multiplexing (OFDM).

For beacon transmissions and to ensure interoperability among Type A devices, a common, mandatory mode is defined based on the SCBT transmission scheme.

Furthermore, a mandatory Discovery Mode is defined to allow the initial communication between Type A devices, prior to antenna training.

A flexible multi-segment frame format is employed.

2.2.1 Single Carrier Block Transmission (SCBT)

- **Employs an adaptive length Cyclic Prefix (4 possible lengths, including 0)**
  - *Allows frequency domain equalization*
  - *Allows time domain equalization*
  - *For good performance in different multipath environments*
- **Particularly important since the level of multipath significantly varies as a function of antenna directionality as well as the environment.**
- **The SCBT modes: $\pi/2$-BPSK, QPSK, $\pi/2$-NS8QAM, 16QAM, UEP-QPSK and UEP-16QAM with multiple code rates**

2.2.1 Single Carrier Block Transmission (SCBT)

- A concatenated Reed-Solomon (RS) and convolutional code is used with for $\pi/2$-BPSK, QPSK modes.
- For the larger constellations Trellis Coded Modulation is concatenated with the same RS code.
- Type A SCBT supports data rates from 0.4Gbps to 6.4 Gbps, without channel bonding.
- Mandatory common beaconing mode is based on $\pi/2$-BPSK at a data rate of 0.4 Gbps.

2.2.2 OFDM

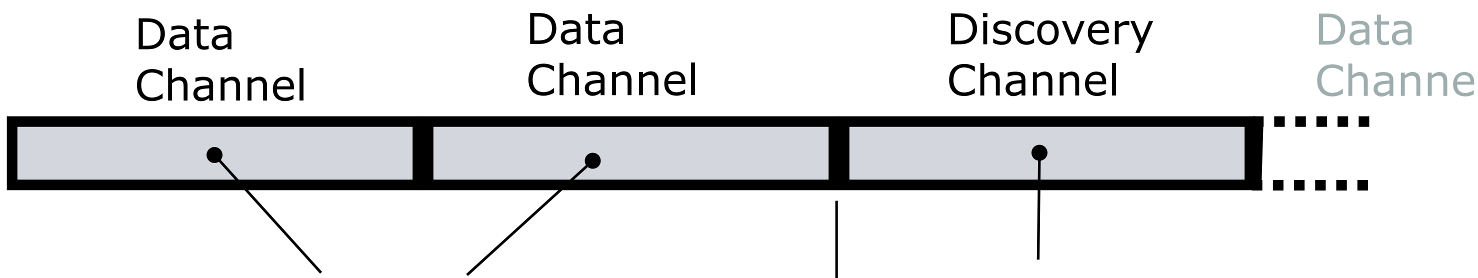
- Incoming data is split into two parallel branches for baseband encoding and interleaving
- Eight different data rates are achieved using four different coding modes along with QPSK and 16-QAM modulation.
- Reed Solomon code is concatenated with convolutional codes to provide coding gain to overcome fading channels
- Eight parallel convolutional encoders are used to keep the cost of ultra-high throughput decoding under control

2.2.2 OFDM

- **The coding modes support diverse application requirements**
  - *Equal Error Protection (EEP) coding*
  - *Unequal Error Protection (UEP) coding*
  - *UEP mapping*
  - *MSB-only*
- **Modes are also combined with an advanced bit interleaver to provide better performance**
- **Efficient OFDM tone interleaver provides error resilience based on bit reversal operation at reduced complexity**

2.2.3 Discovery mode and antenna training

Channel bandwidth: 2.16 GHz



- Data Channel Bit Rate: up to 6.4 Gbps
- Just Antenna Tracking – No Training
- High Performance Antenna Patterns
- DRP
- Provides QoS

- Discovery Bit Rate: ~1 Mbps
- neighbour Discovery
- Antenna Training
- CSMA Data Access: >1 Gbps
- No QoS

2.3 Type B PHY

- Type B
  - minimizes the complexity and power consumption of the receiver
  - Uses DBPSK waveform instead of $\pi/2$-BPSK
  - Uses Reed-Solomon (RS) FEC instead of concatenated RS and convolutional code
- Uses a simplified single carrier transmission scheme
  - Allows for both simple coherent and non-coherent demodulation
  - Minimizes the implementation overhead for support interoperability with Type A devices
  - Uses the same frame format as Type A beacon

2.3 Type B PHY

- The Type B device does not support
  - Cyclic prefix
  - Discovery mode used for antenna training
- Optional
  - Waveforms: DQPSK, UEP-QPSK, Dual AMI and 4ASK
  - Flexible multi-segment frame format
  - Multiple sectors antennas (non-trainable antennas)
  - Transmit antenna training sequences to assist Type A device antenna training
- Transmission rate of a Type B device: 0.8 Gbps, optionally 1.6 Gbps and 3.2 Gbps.

2.4 Type C PHY

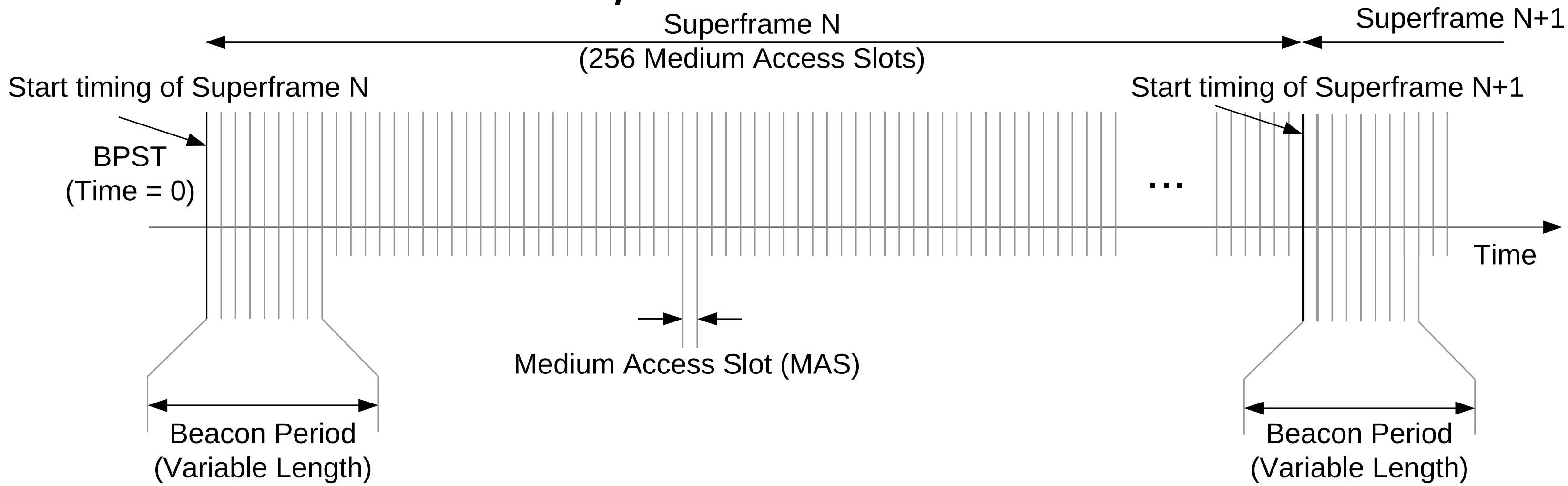
- Uses simple Amplitude-Shift-Keying (ASK) modulation
  - Allows for both coherent and non-coherent detection
- For management and interoperability with Type A or Type B devices, the
  - On-Off-Keying (OOK: 2 level ASK) with 2 symbols repetition for beaconing (polling) mode
  - Optional closed loop transmission power control for better channel reuse and power saving

2.4 Type C PHY

- Does not support
  - multi-segment frame format
  - adjacent channel bonding
  - antenna training
  - convolutional coding FEC
  - UEP
- Uses Reed-Solomon FEC
- Transmission rate: 0.8 Gbps (non-coherent OOK), optionally 1.6 Gbps and 3.2 Gbps (non-coherent 4-level ASK)

3.1 A unified superframe structure

MAC superframe structure



	Beacon	DRP
Type A:	SCBT	SCBT / OFDM / OOK/4ASK
Type B:	DBPSK / SCBT*	DBPSK / DQPSK / UEP-QPSK / Dual AMI / OOK/4ASK
Type C:	No Beacon	OOK /4ASK

* Transmit Only

3.2 Device discovery

- Devices discover each other through transmission of beacon and polling frames in the Discovery Channel.

- Transmitters of beacon or polling frames in the Discovery Channel use CSMA/CA with random backoff so that all devices have a fair and quick channel access to discover other devices.

- Based on the device types, devices follow different procedures using their own mandatory PHY modes:
    - Type A devices can discover each other via transmission and reception of omni-directional mode-D0 beacons in a peer-to-peer manner
    - Type B/Type C devices can discover the devices of their own types via directional mode-B0 beacons/mode-C0 polls respectively.
    - Device discovery among heterogeneous types is achieved through polling based mechanisms on a master-slave basis.

3.3 Beacon transmission

- Devices send beacon/polling frames to their neighbours to exchange coordination information such as reservation of channel time or time synchronization.

- Unlike omni-directional beacon transmission in ECMA-368, beacons are transmitted using directional antennas to support simultaneous connections (thus, maximizing the spatial reuse).

- Devices of Type A or B, transmit beacons in unique beacons slots within the beacon period of each superframe using the enhanced ECMA-368 Beacon Protocol.

- A Type C device only needs to send polling/response frames in a master-slave period to announce its presence.

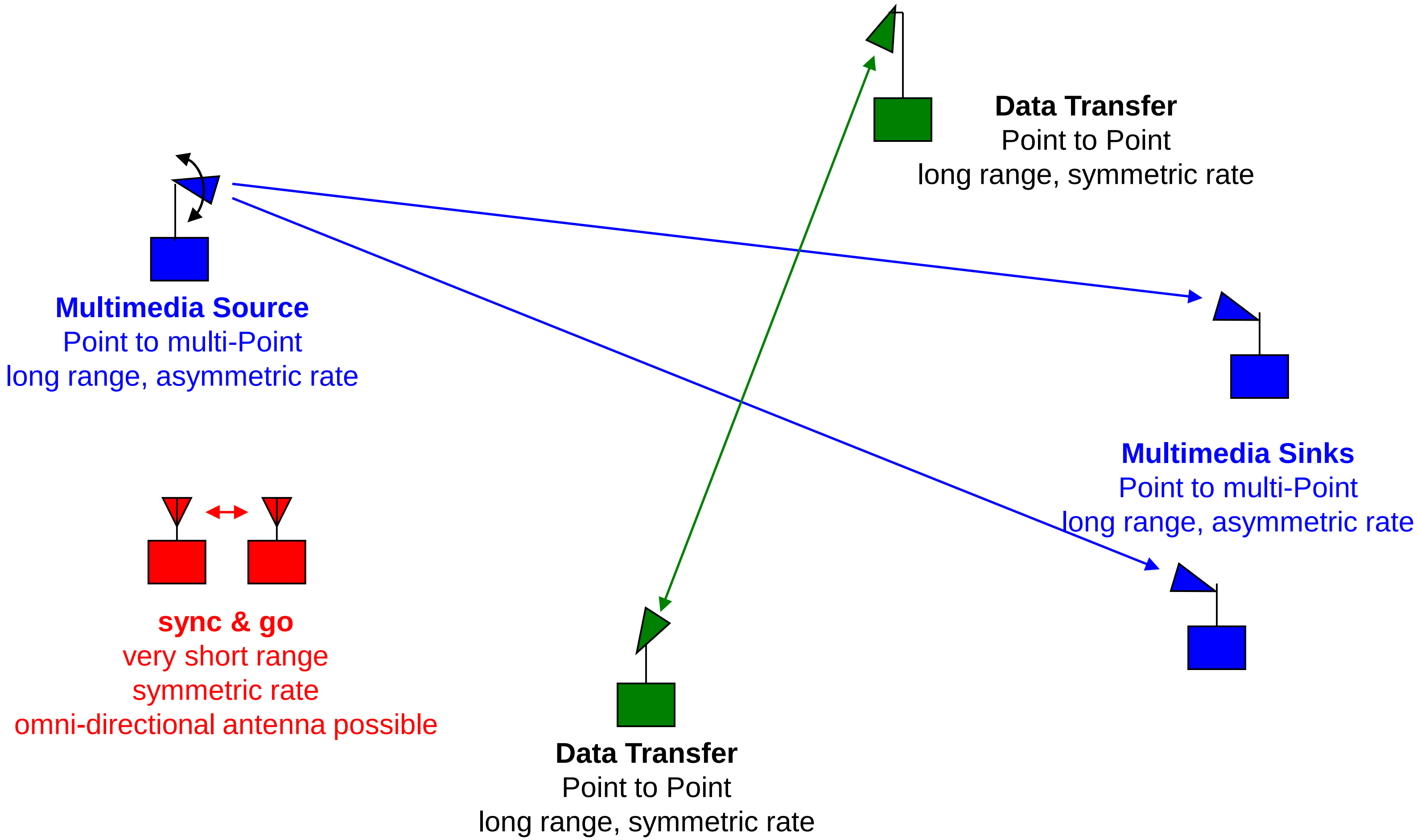
3.3 Beacon transmission

- A device might send more than one beacon because a single directional beacon might not be heard by all devices with which the device needs to communicate due to the narrower beam used in the beacon transmission.

- A Type B device needs to send a Type A beacon along with each transmitted Type B beacon (referred to as a dual beacon) so that Type A devices will not interfere with the Type B devices.

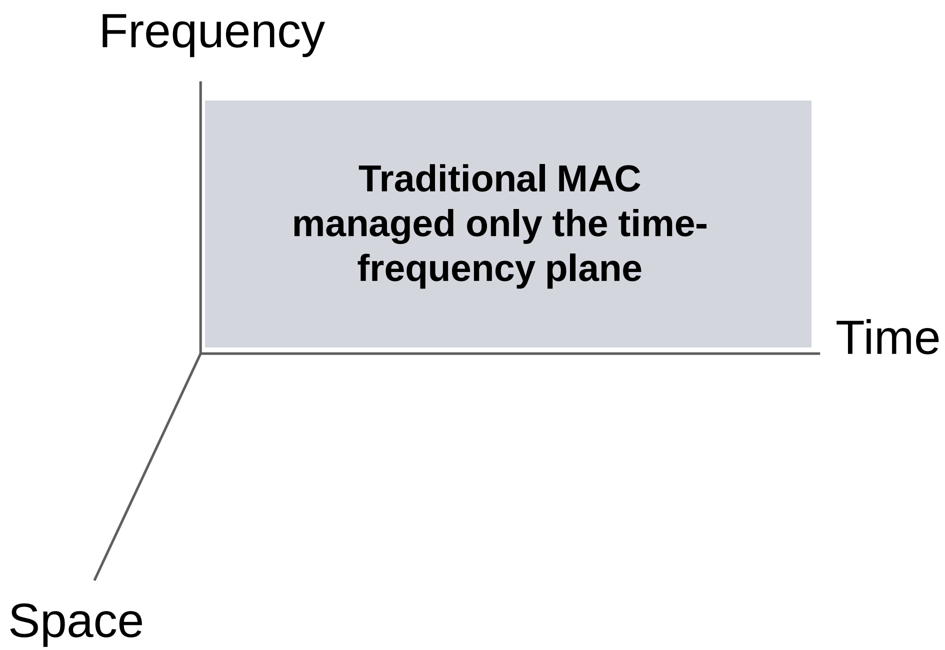
- A Type C device has to surrender the channel usage by stopping the transmission of polling/response frames when sensing the presence of any type A or type B device (DAA).

3.4 Spatial reuse



3.4 Spatial reuse

The 60 GHz MAC needs to manage the time-frequency-spatial space

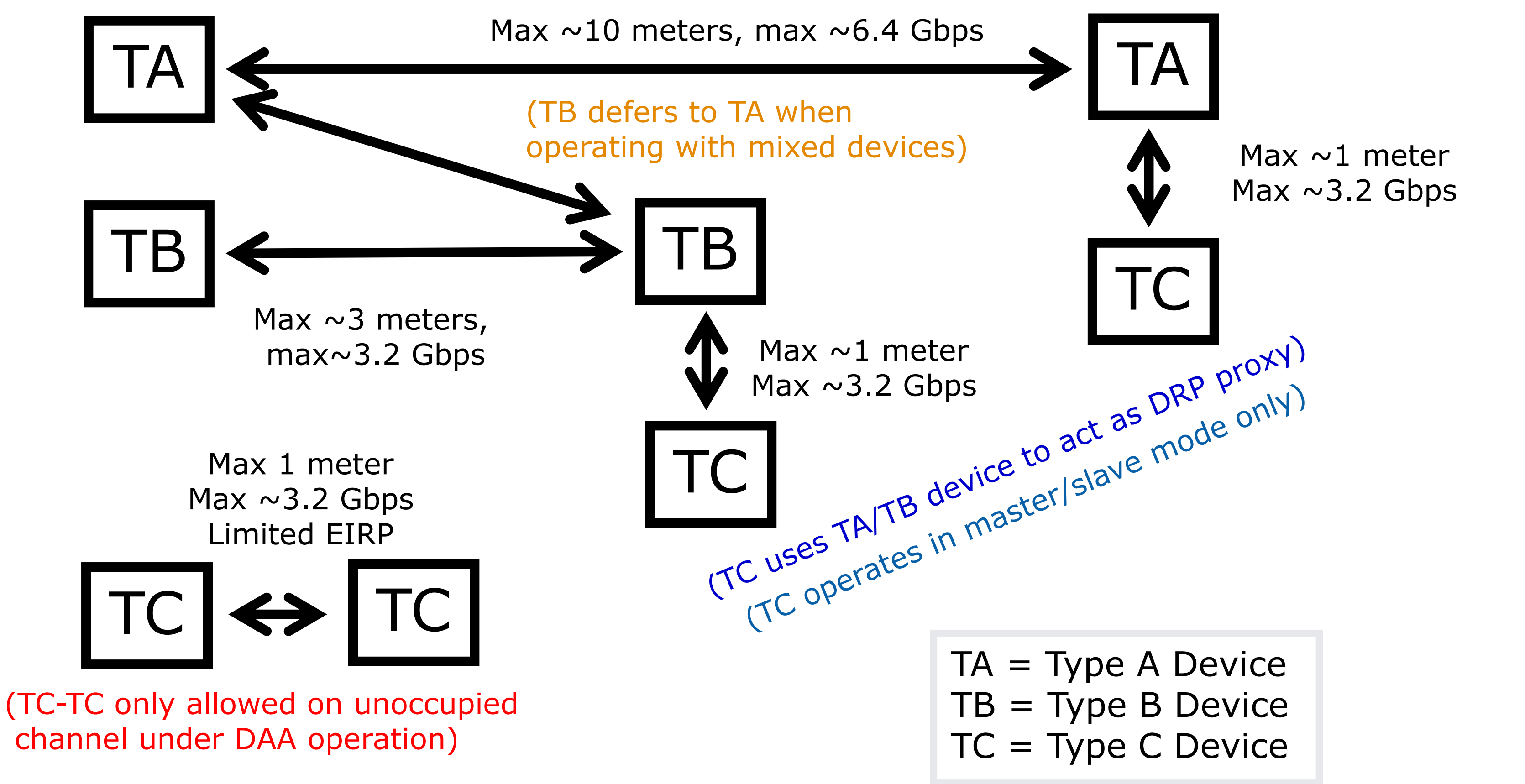


3.4 Spatial reuse

60 GHz is using Modified ECMA-368 MAC Distributed MAC Modified to accommodate Directional Antennas

- ***Distributed MAC allows distributed coexistence***
    - each node strives to avoid interference
    - inherent support for spatial reuse
- ***Distributed MAC circumvents the central controller issue***
    - mixed device types with different range capabilities makes central control problematic
- **Inherited from Ecma-368**
    - distributed control via device beaconing
    - reservation based medium access (DRP)
    - security
- **Modification necessary to support spatial reuse**
    - needed to add antenna training protocol

3.5 Coexistence and interoperability

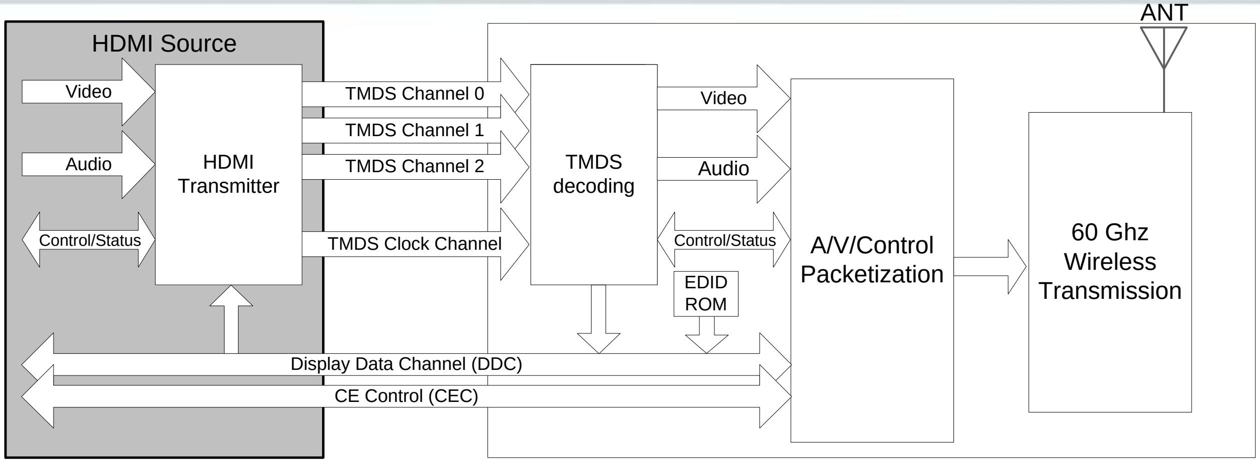


3.6 Other features

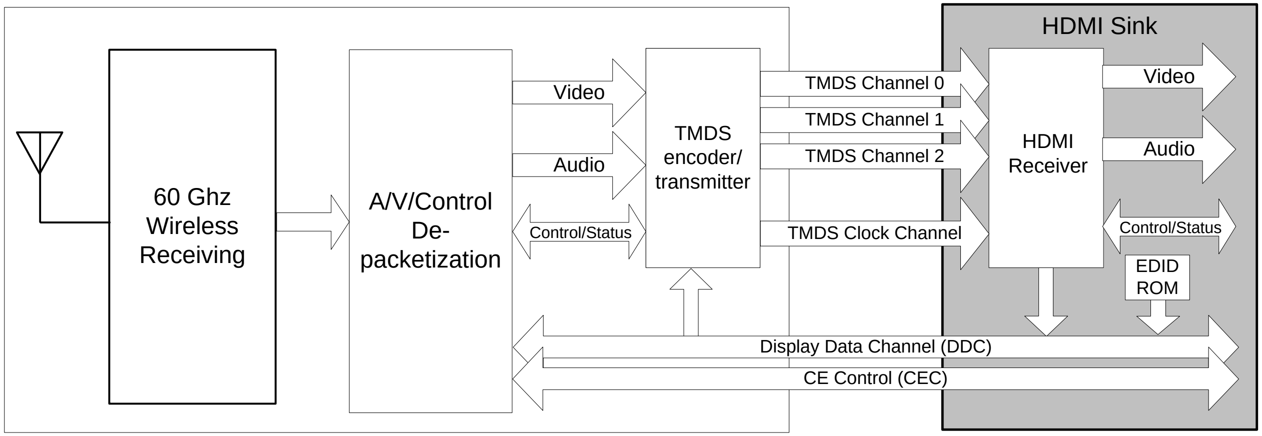
<u>The MAC protocol also supports …</u>

- Transmit power control
- Out of band control channel
- Dynamic relay transmission for blocked links

Wireless HDMI transmitter



Wireless HDMI receiver



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Status and plan