Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [PicoCast MAC Protocol]
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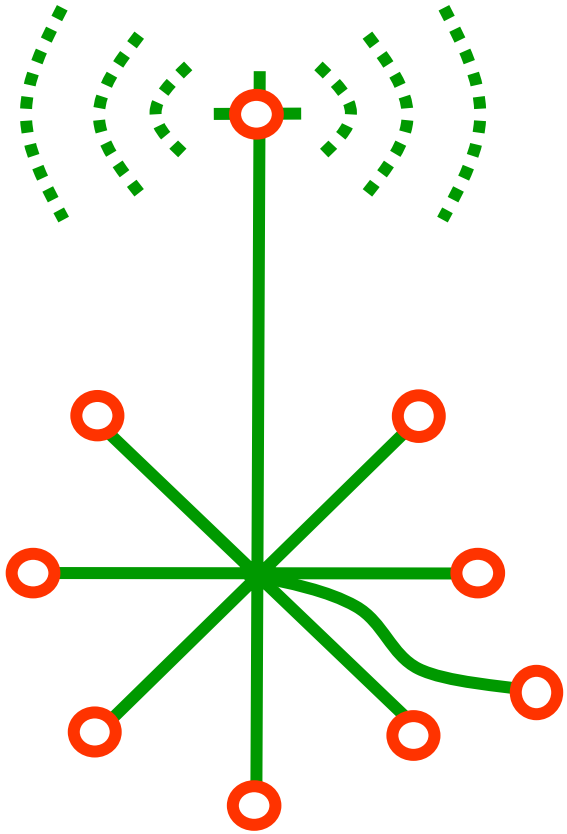
Re: [Contribution to IEEE 802.15.6 Meeting, March 2009]

Abstract: [PicoCast MAC protocol support most of WBAN requirements. Container (Synchronous Frame Set) concept is suitable to support user oriented service convergence and avoid mutual interference. PicoCast single MAC can support multi PHYs and scalable different speed.]

Purpose: [Proposal]

PicoCast MAC Protocol



March 2009

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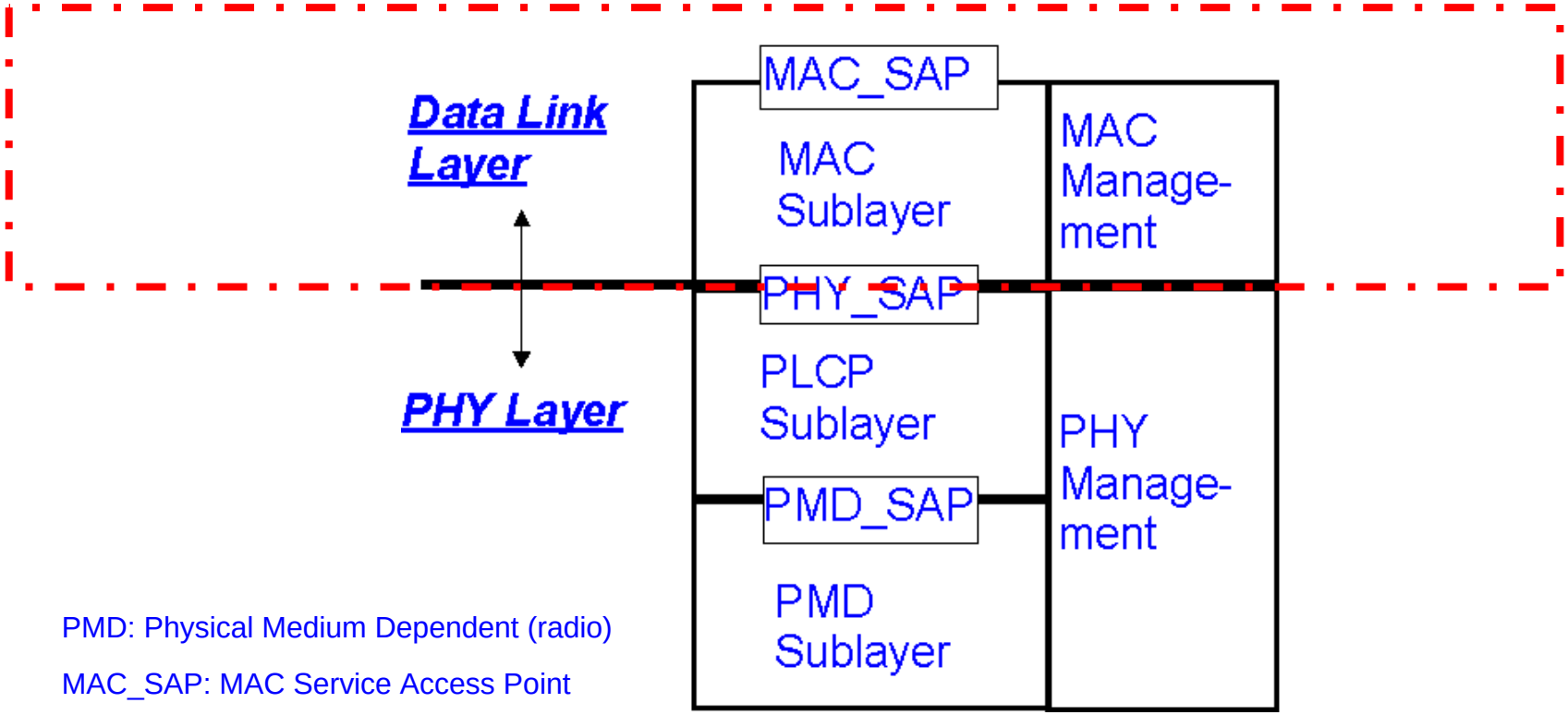
PicoCast MAC Position



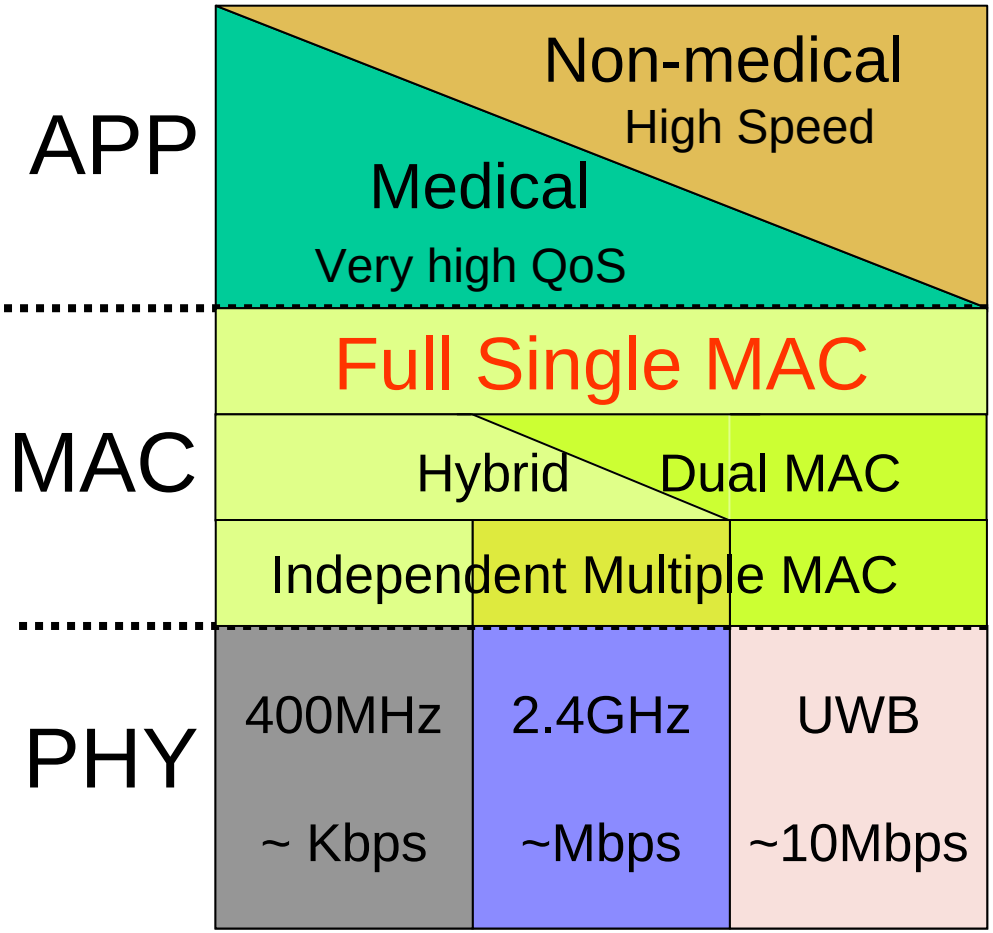
PMD: Physical Medium Dependent (radio)

MAC_SAP: MAC Service Access Point

PHY_SAP: PHY Service Access Point

PLCP: PHY Layer Convergence Protocol

Issues in WBAN Work Scope



Arrange Requirements

- List up user requirements
- Check realizability
- If no, reduce requirements

Challenges & Opportunities

- Near / Far Interference
- Single MAC for Multiple PHYs
- Compromise power & speed
- Medical / Non-medical dual support

Choose existing technique

- Select good chip
- Enhance antenna matching
- Reduce system size & Good design
- Add process gain for medical use

Solutions for Challenges

1. Near / Far Interference

- Chg. : Even though difference frequency band interfere each other
- Sol. : Synchronized Frame can reject mutual interference among PHYs
  128bit multi preamble is necessary to enhance sync. probability

2. Single MAC to support Multi-PHYs

- Chg. : Single PHY cannot meet so wide user requirements
- Sol. : Container Concept accommodates various information Boxes
  Synchronized Frame can support different PHYs without interference

3. Compromise Power & Speed

- Chg. : Low power sensor and High speed multimedia should support
- Sol. : Multi PHY concept can support Multi RF Block
  Sensor use single RF Block, Multimedia use multi RF Block's

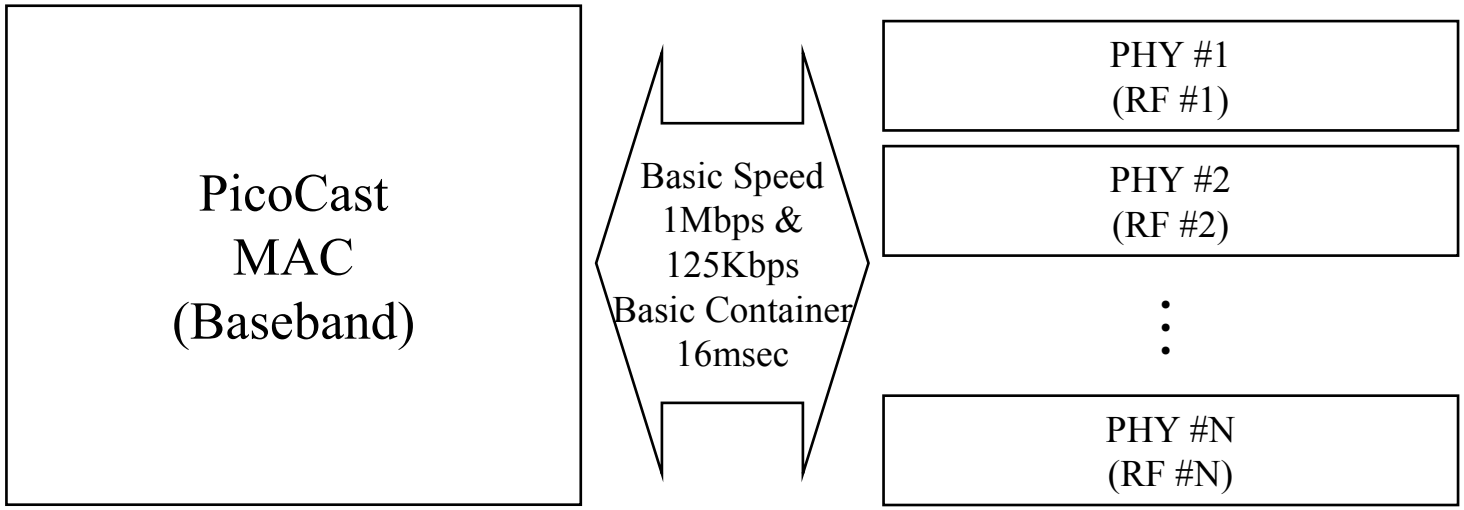
4. Medical / Non-Medical Dual support

- Chg. : Medical needs 10^{-10} BER performance with low speed
- Sol. : 128bit Multi preamble provides enough Process Gain
  We can use 128bit multi preambles as 1 or 4bit data symbols

PicoCast MAC Protocol Features

- **Single MAC for Multiple PHYs** (1,2,3,10,11,12,14)
  - Open structure for any PHY with the suggested interface.
  - Support time control for synchronized container concept.
- **Synchronized Container Concept** (7,9,10,11,13,14)
  - Sensor, data, & multimedia box's can be shipped with a same container
  - Every same size container should be synchronized to avoid interference
  - Every container must reserve the first slot for the control box.
- **128bit length Multiple Preambles** (3,4,5,6,7,9,10,12,13,14)
  - 127 Preambles(128bits length) are used for different usages.
  - Emergency, short command, synchronization, priority, hand-over & etc
  - Support data integrity for important medical information as 1bit symbol
- **Hierarchical Code structure & Self Frequency Planning** (1,6,7,8,9,13,14)
  - Group Code, Scan Code, & Security Code are used for various applications.
  - Scan Code supports sounding algorithm to choose the best frequency set.
- **Adaptive Common Channel Signaling** (7,8,9,10,12,13,14)
  - 16 containers are composed to one vessel(256msec).
  - Control Boxes are used for adaptive common channel signaling

PHY(RF) independent MAC (Baseband)

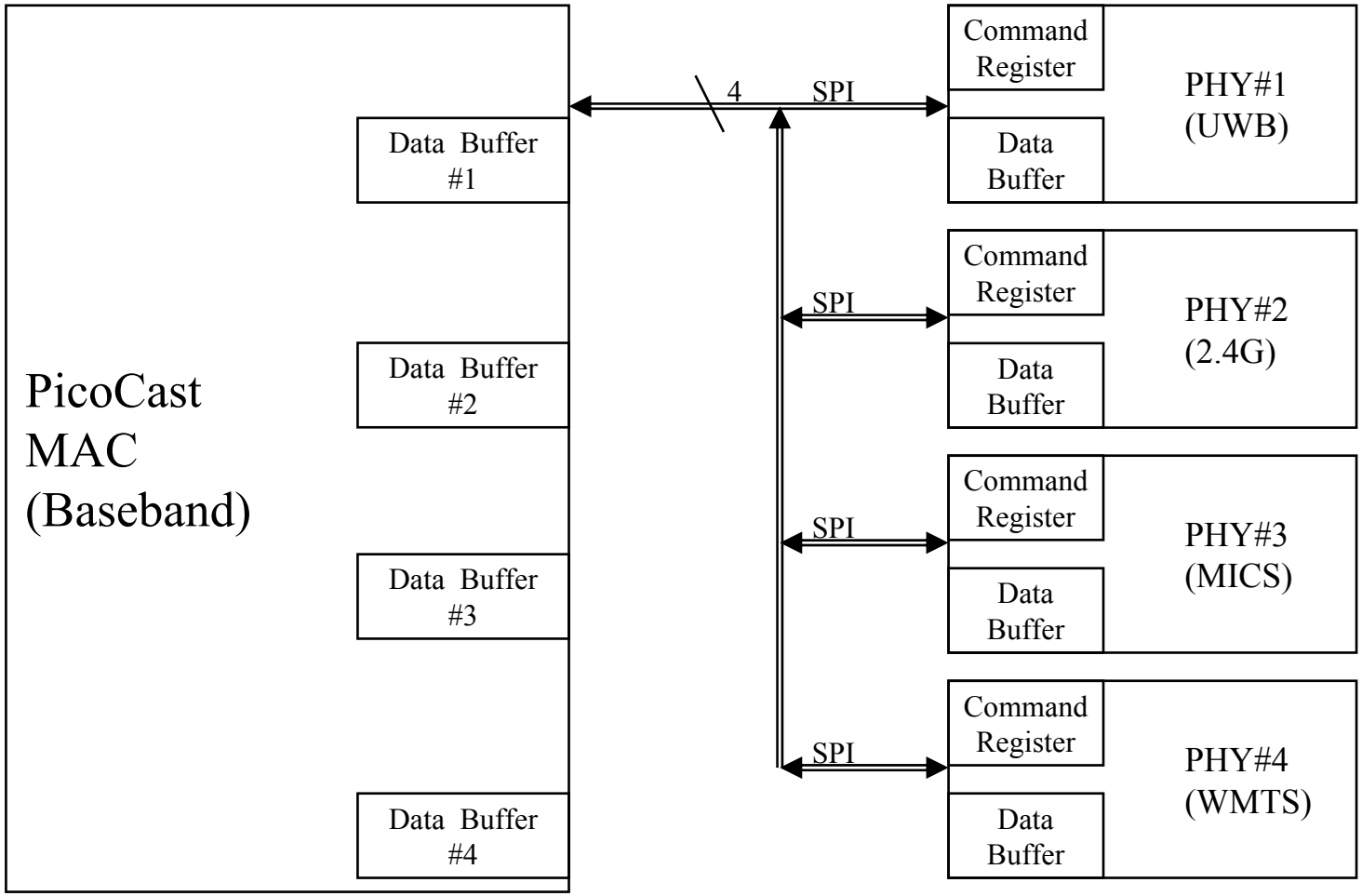


- **PHY Type : 2.4G RF, UWB, WMTS, MICS, & etc.**
- **PHY Interface : Synchronized Container Base**
- **Basic Speed : 1Mbps (125Kbps for MICS)**
- **Special Features :**
  - **Container Synchronized Interference Rejection**
  - **Scalable data rate depend on PHY**

PHY(RF) Requirements

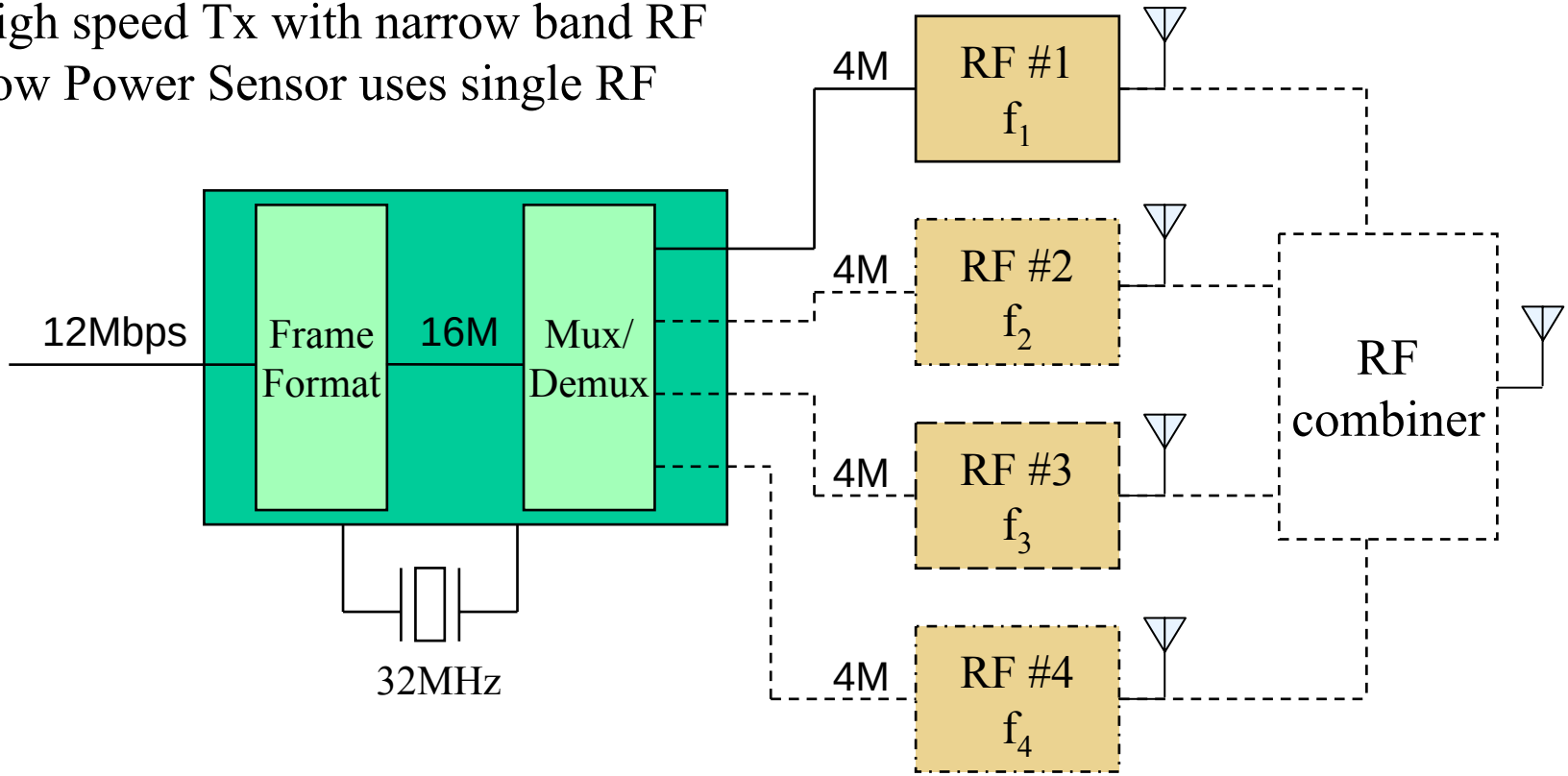
- Shall satisfy WBAN Requirement
  (TG6 Technical Requirements Document)
- Support the operation of Box structure
  - Box Size : 400 μsec ~ 15.2msec
  - Basic Data Rate : 1Mbps
  - Scalable Data Rate : 250K,500K,1M, 2M,4M,8M,16Mbps (option)
  - Lock Time : Less than 500μsec (230μsec recommended)
  - End of Box (EOB) : Less than 300μsec (40μsec recommended)
  - Operation Mode : Tx / Rx / Idle / Sleep / Power-off
  - Write Parameters : Frequency, Power Level
  - Read Parameters : RSSI, Frequency Drift
  - Clock Stability : Less than 20ppm
- Special Requirements for low speed MICS Frequency
  - Basic Data Rate : 125Kbps
  - Minimum Box Size : 1.3msec (single Command Box)
  - Linear Modulation to achieve spread spectrum process gain
  - Control Box slot would be reserved for future usage

Example of PHY Interface with SPI

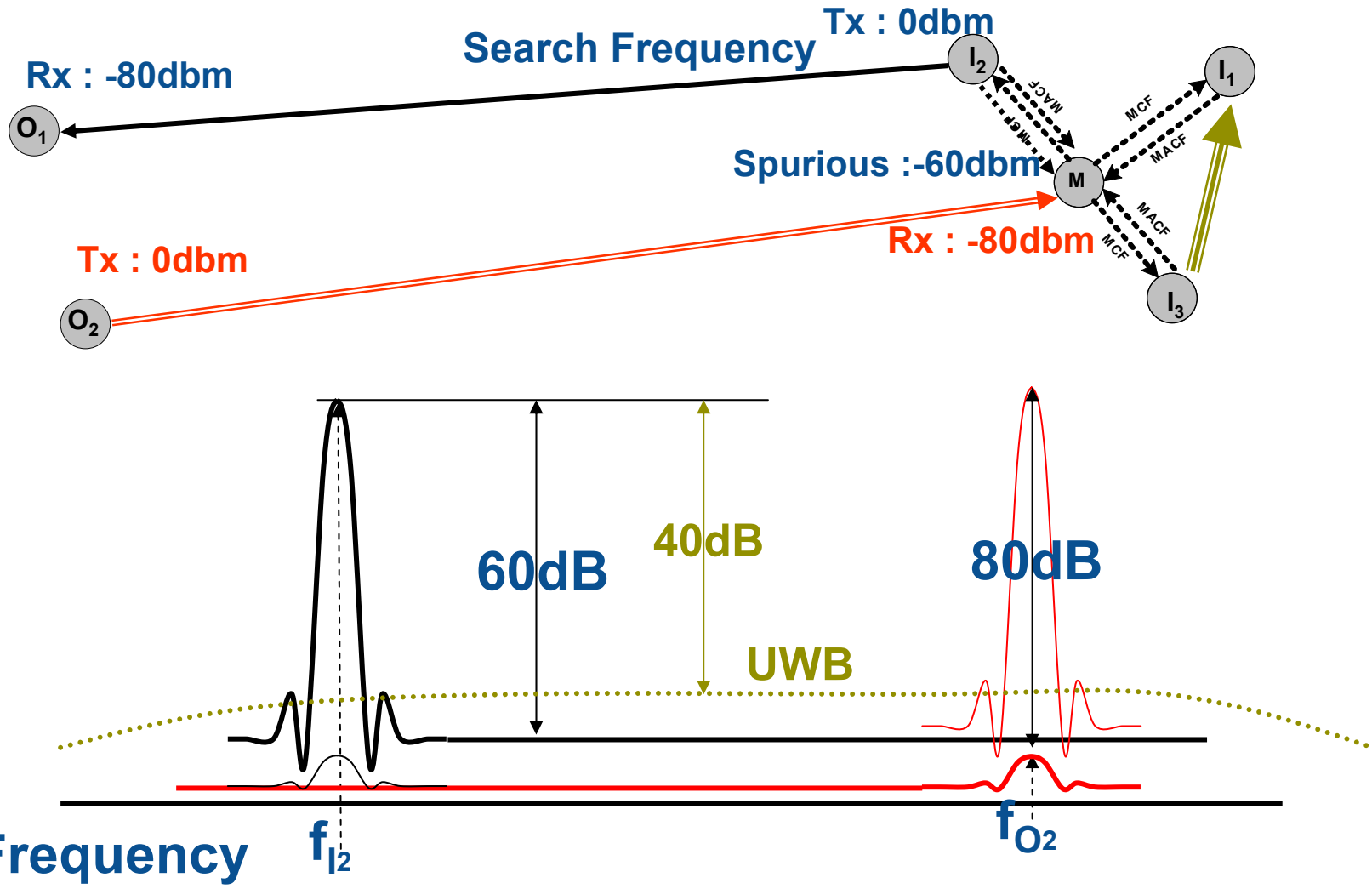


Example of Multi RF Application

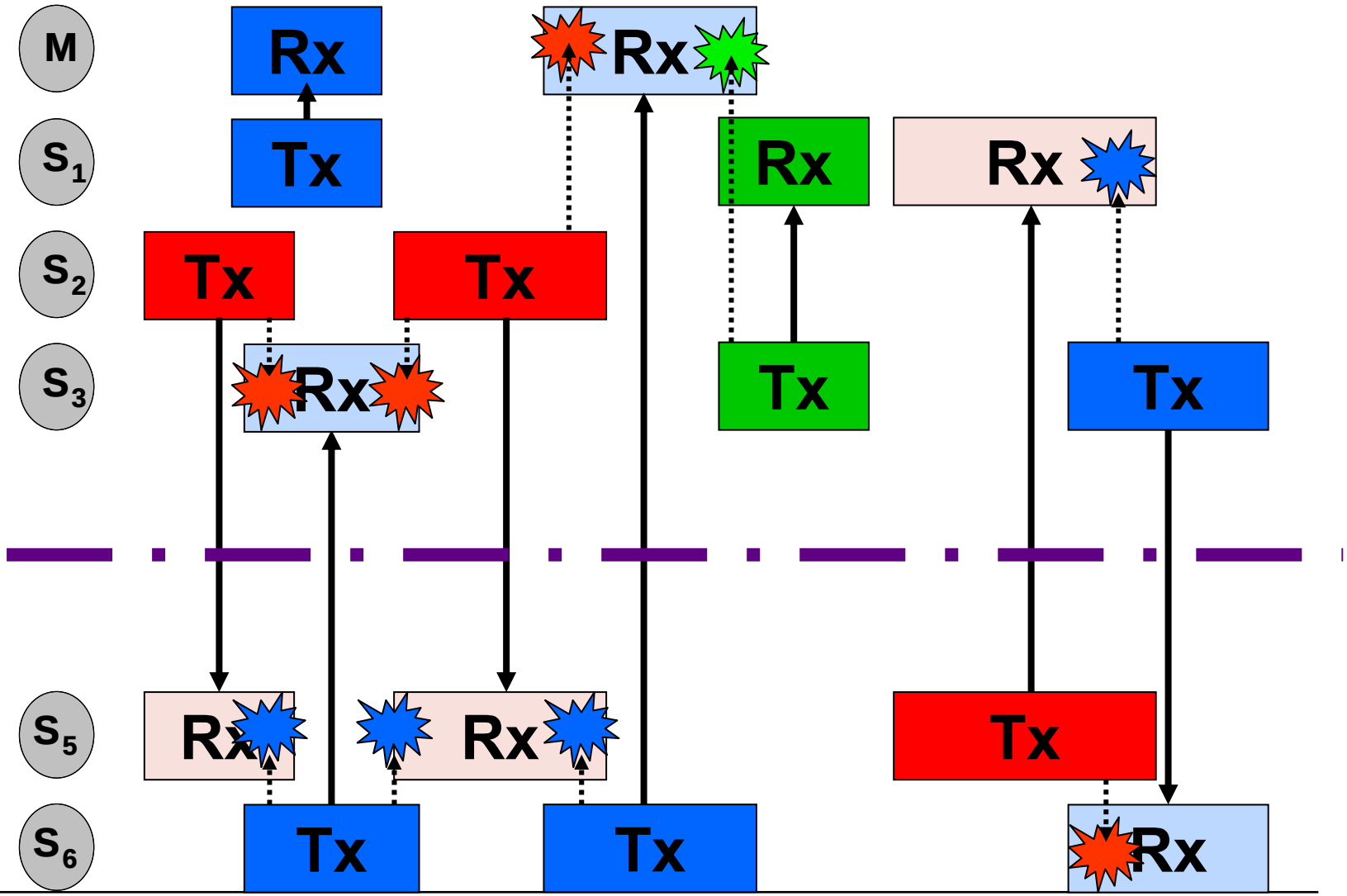
- Frequency Diversity
- High speed Tx with narrow band RF
- Low Power Sensor uses single RF



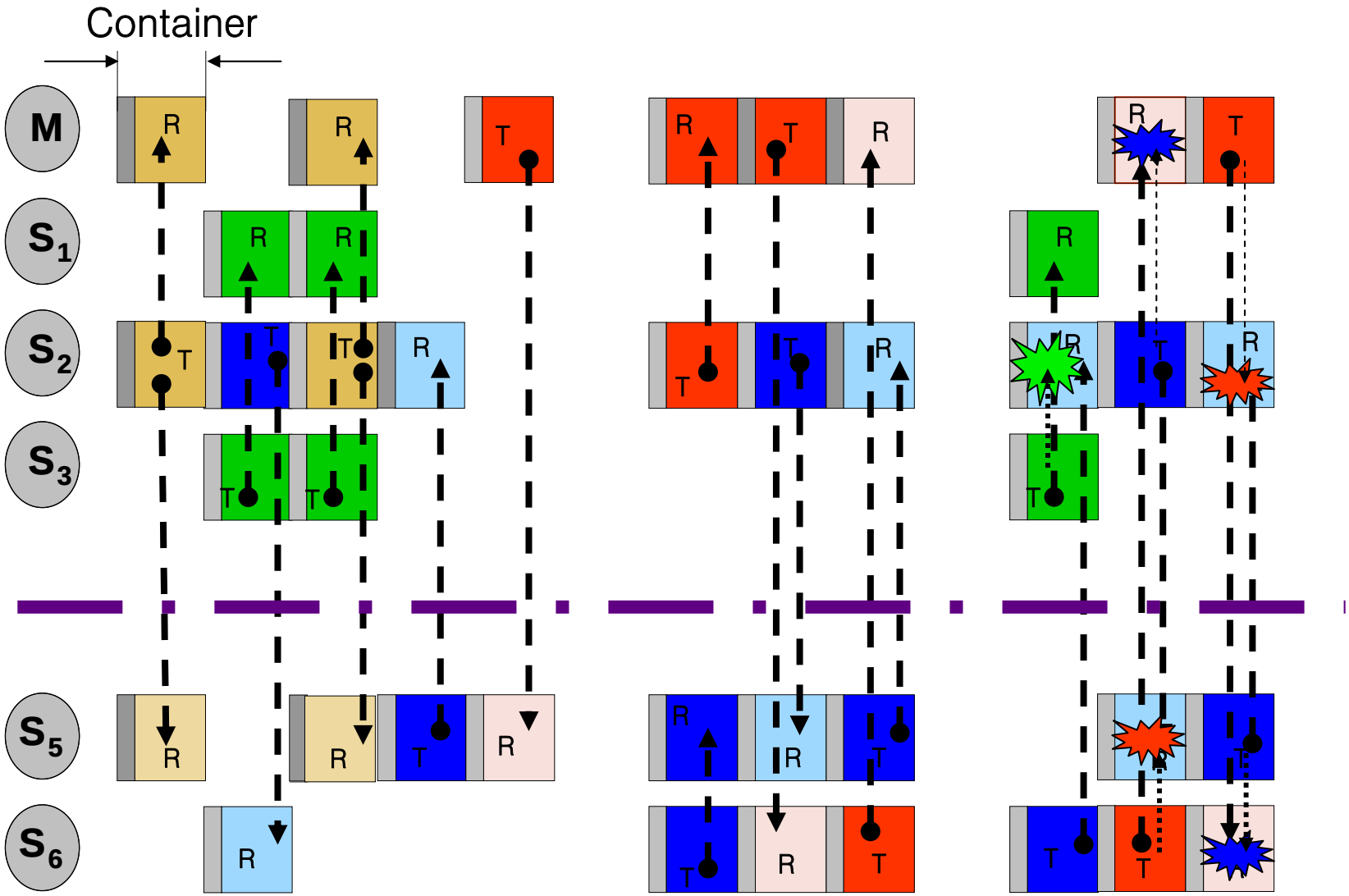
Near / Far Interference



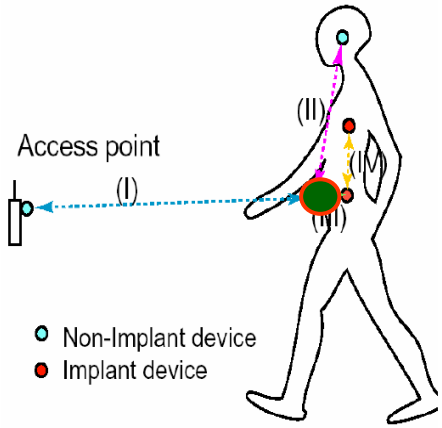
Mutual Interference of existing solution

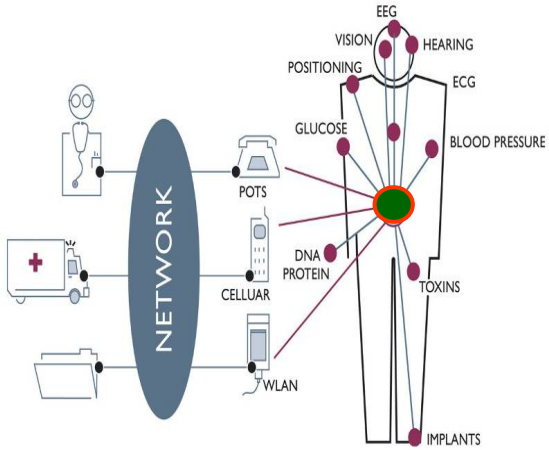


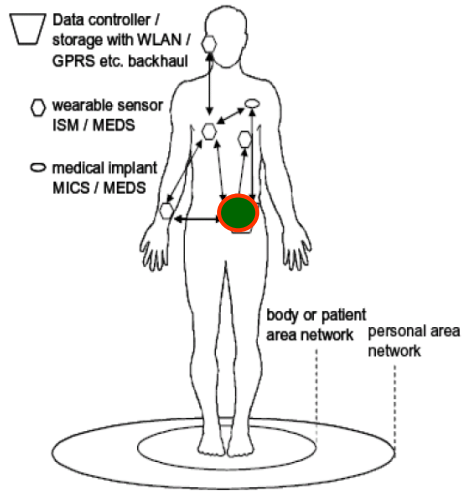
How to avoid mutual interference



Body Coordinator ➔ Mobile Femto-cell



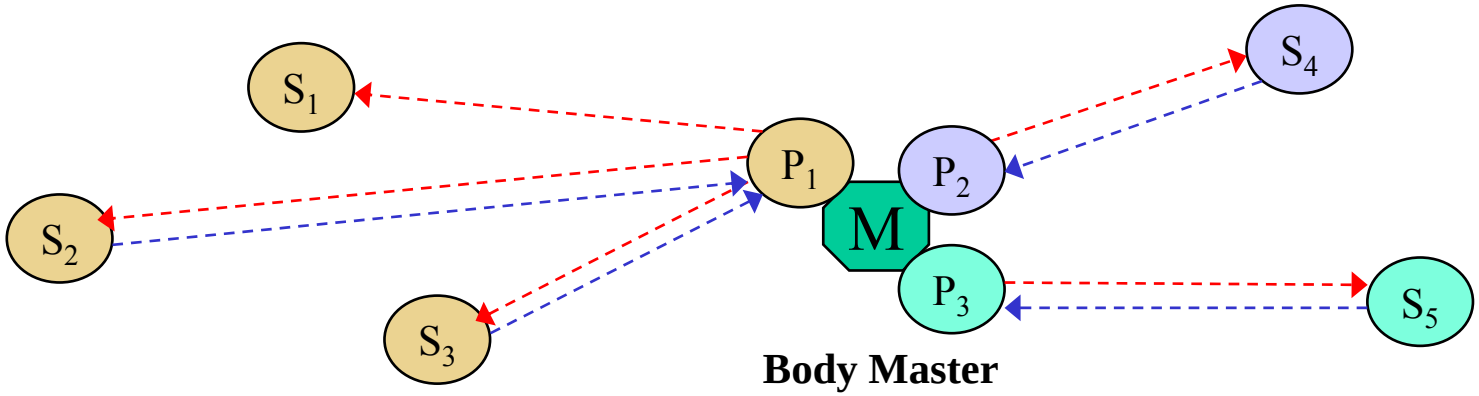


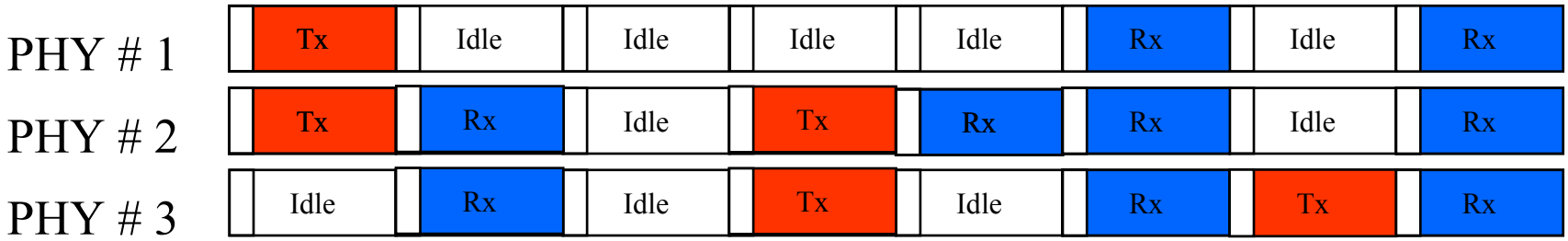


Body Master

- **Body coordinator is not a suitable concept.**
  - **Synchronous frames can reject mutual interference among RFs .**
  - **So, Body coordinator should synchronize all of body devices.**
- **Better to rename body coordinator as “Body Master”.**

Synchronized Container Concept

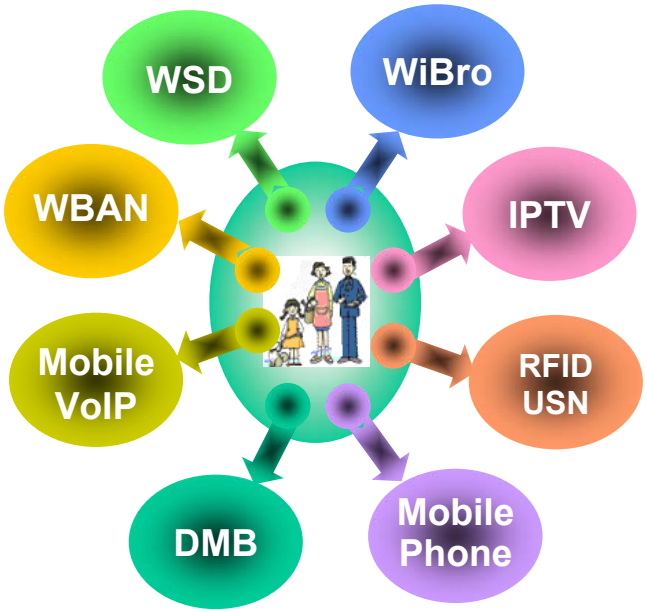




- Avoid mutual interference among PHYs in body master
  - Shall not receive during other PHY is transmitting.
  - Transmit together at the same time.
- Low speed MICS ignores control box time slot.

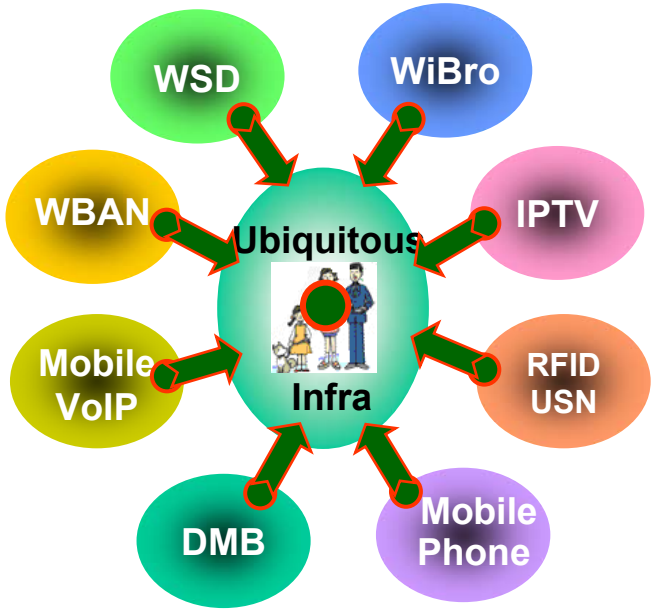
Paradigm Shift : User Oriented

Provider Oriented



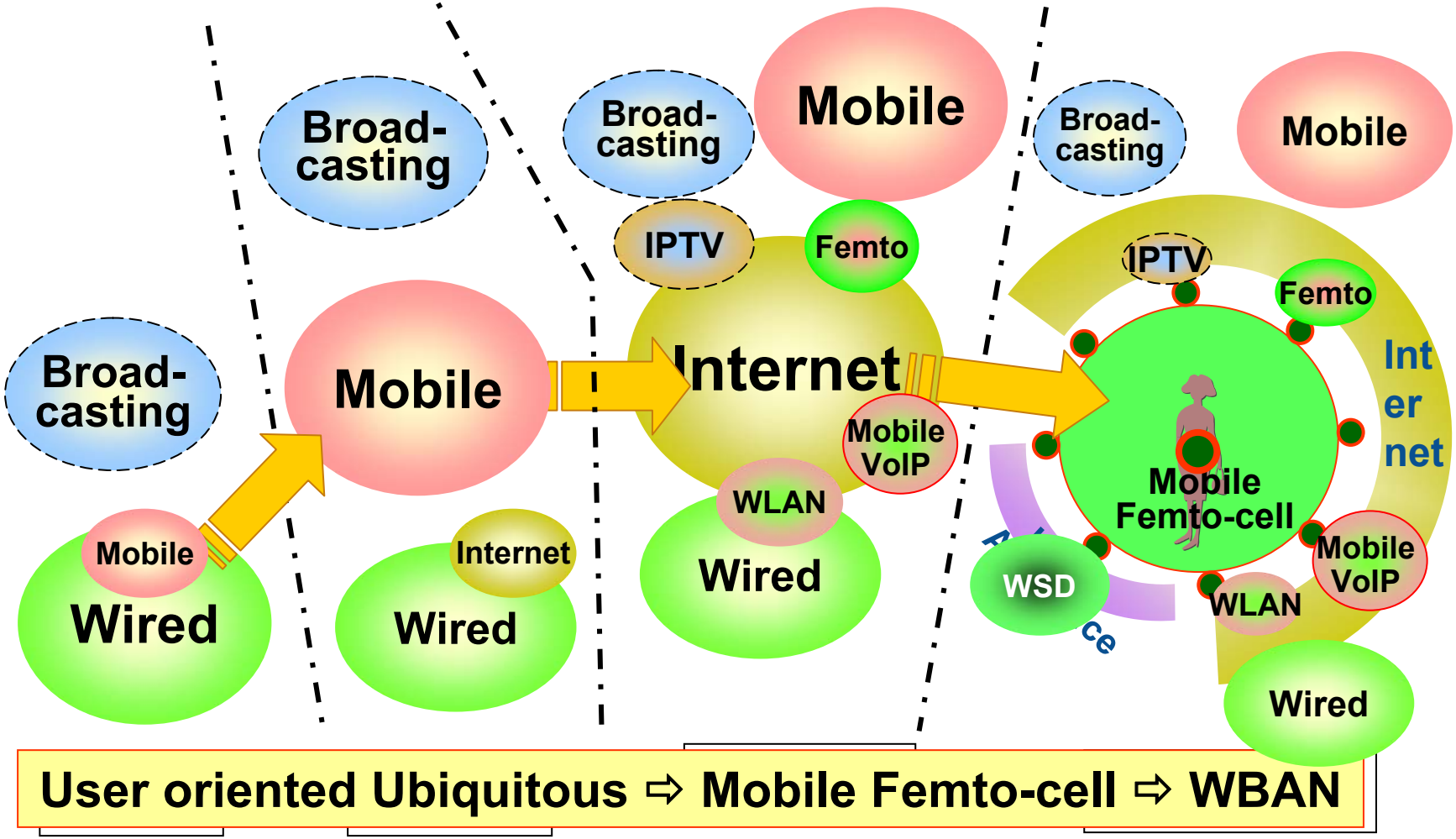
User terminals should meet provider specifications

User Oriented

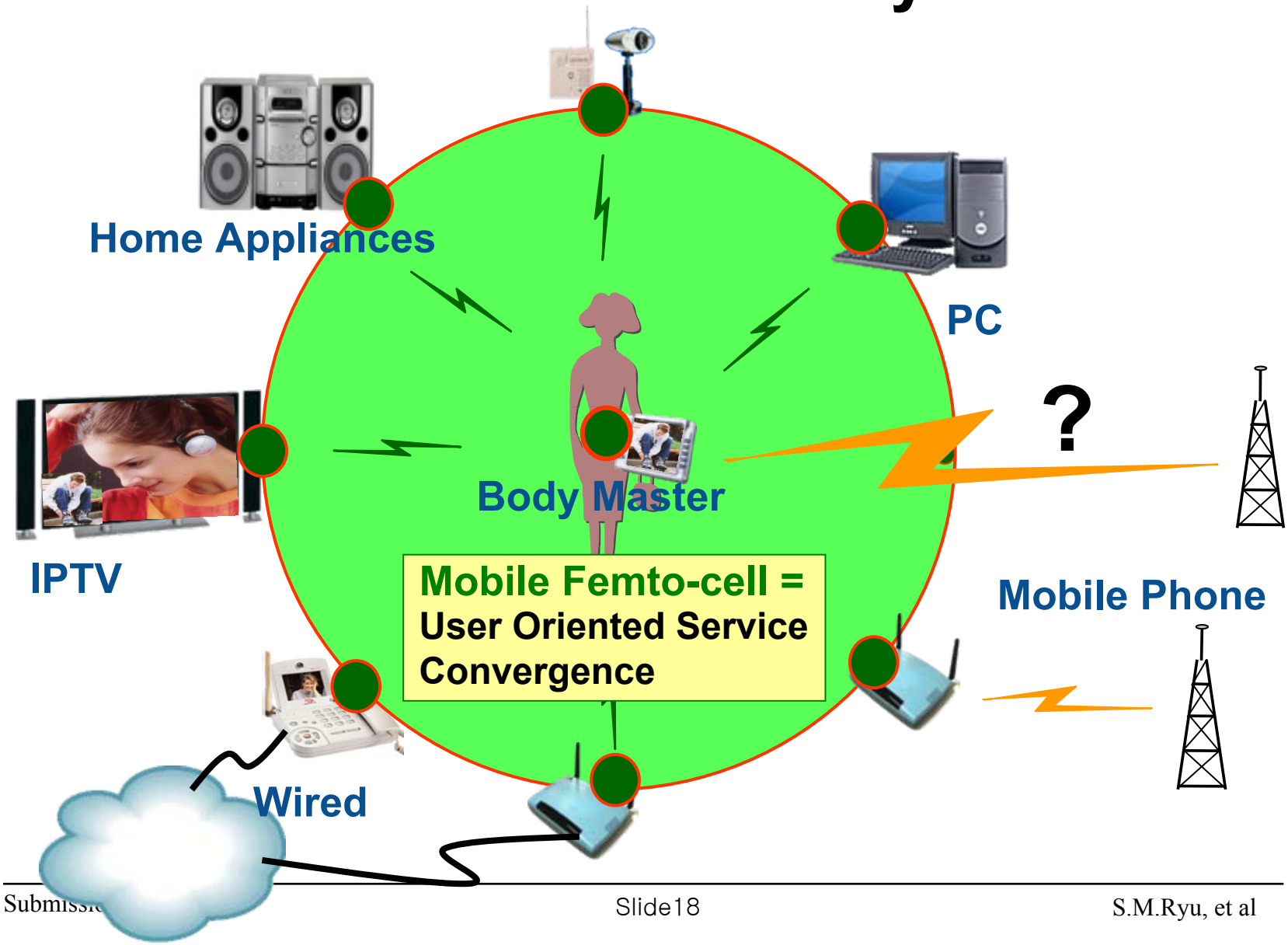


Users select among services broadcast by providers

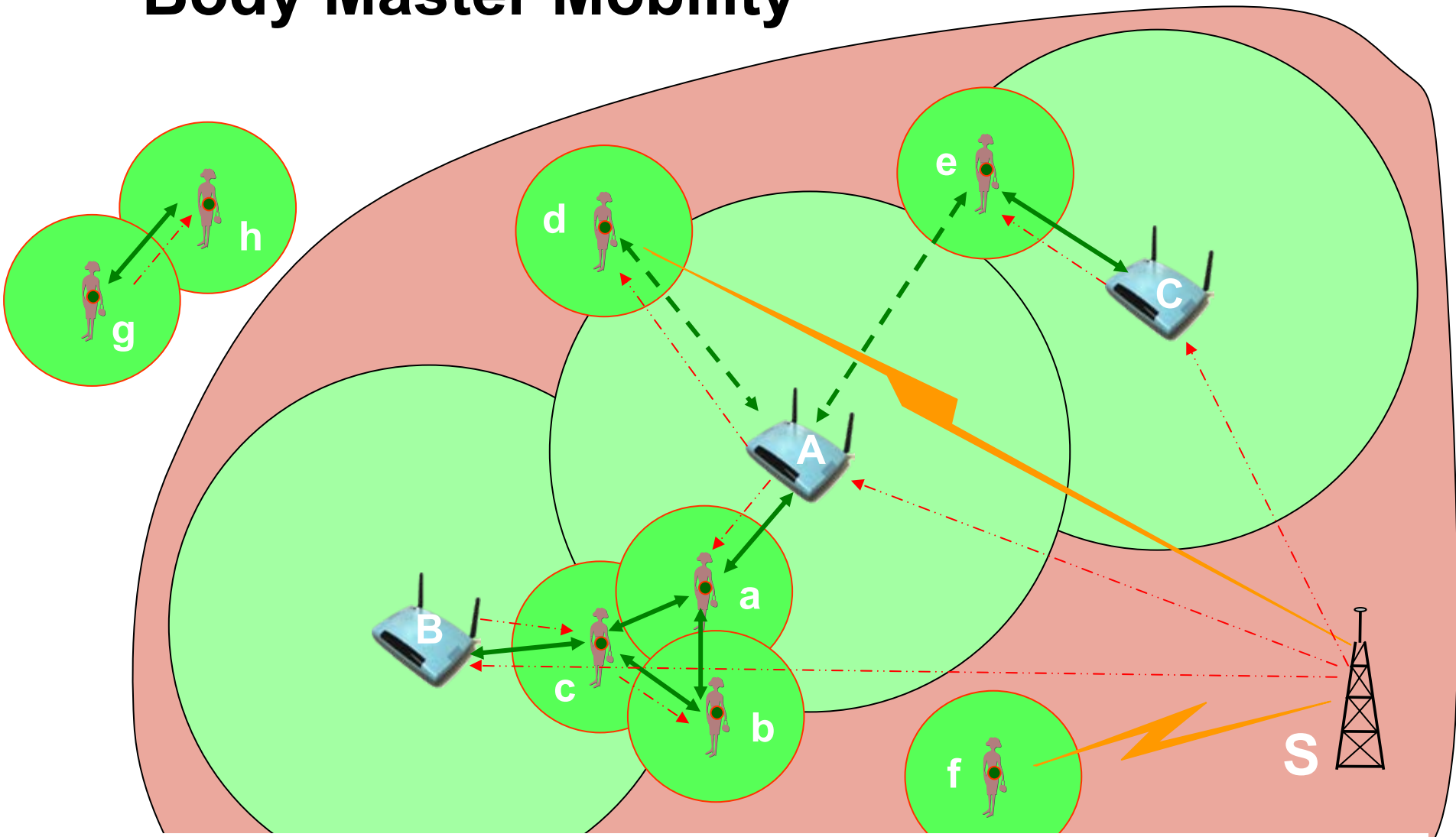
Market Initiative ⇨ WBAN



Mobile Femto-cell = Body Master

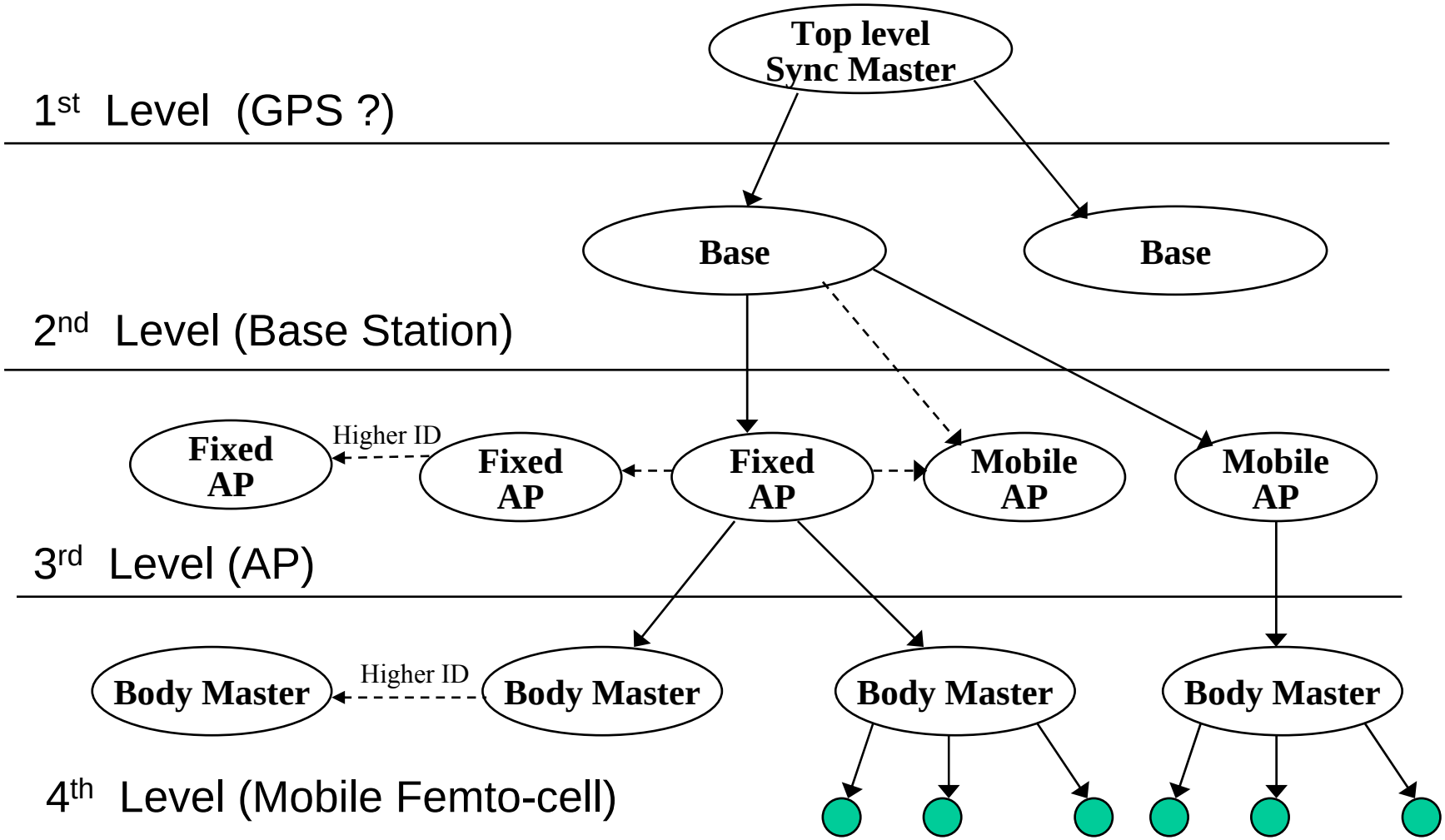


Body Master Mobility



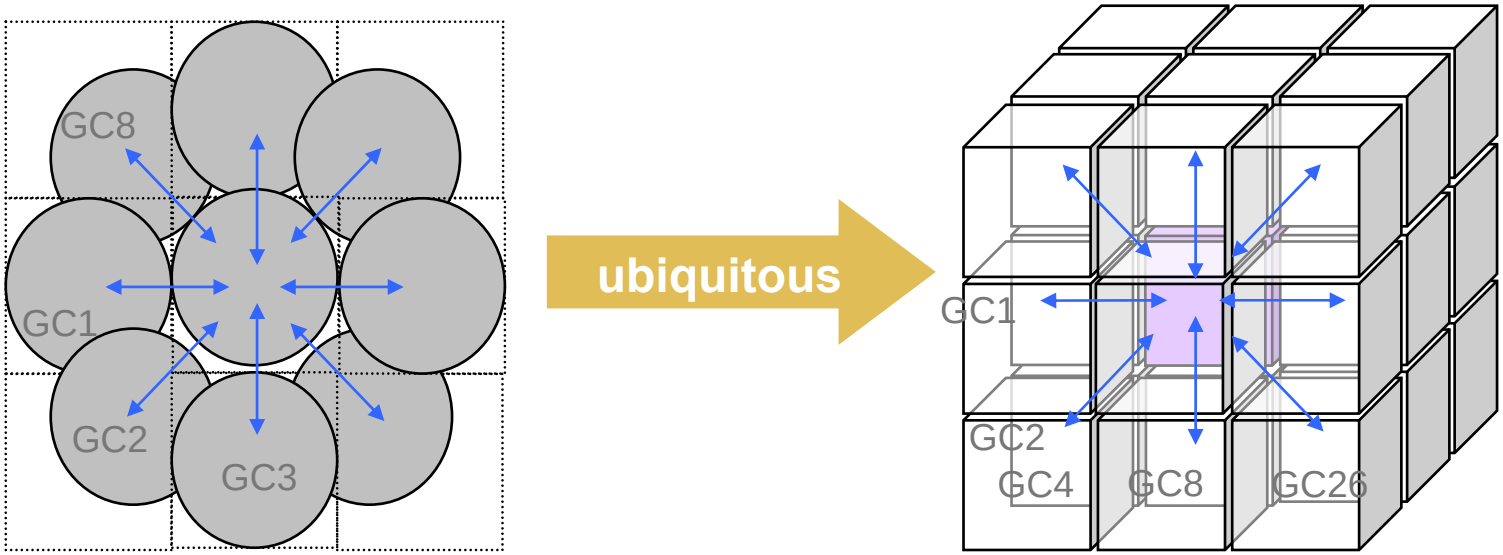
To reduce mutual interference, perfect synchronization is necessary

Hierarchical Sync Structure



Ubiquitous Cell Planning

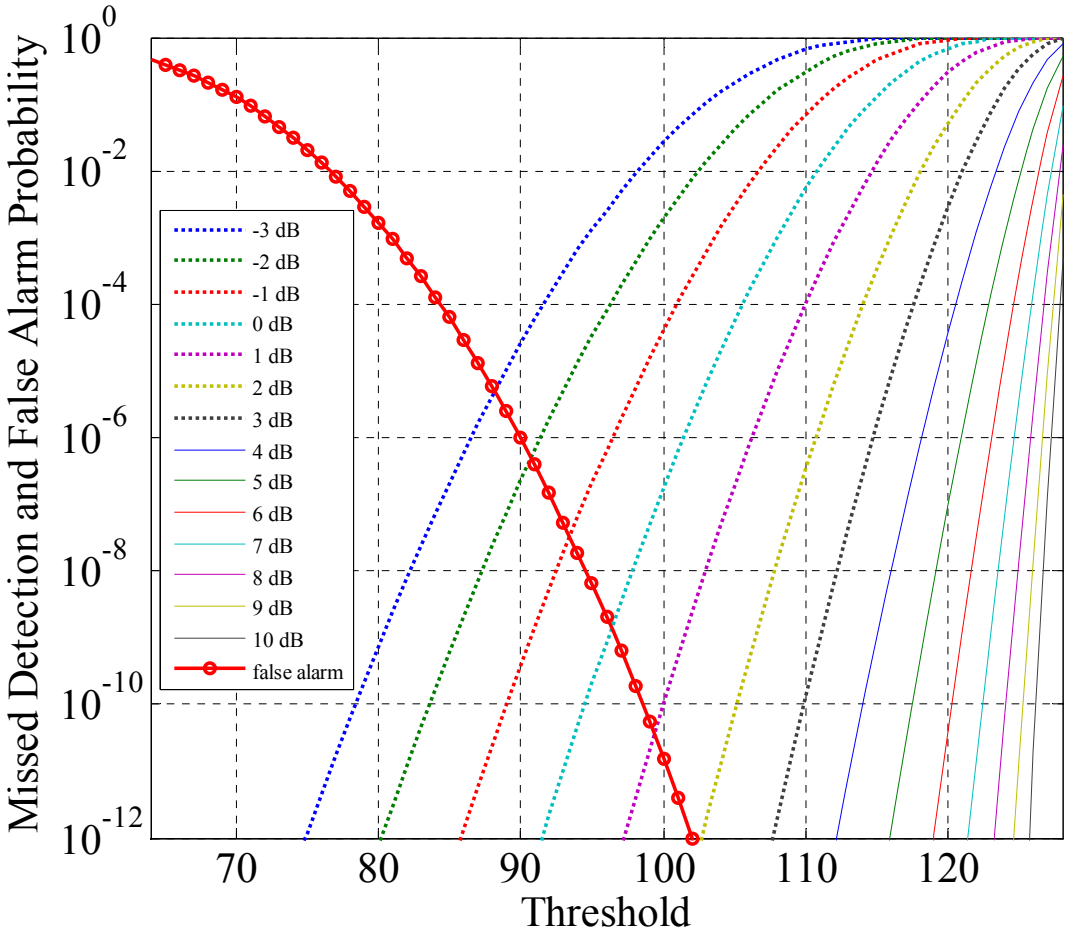
- 2-D
- 3-D



Self Organizing MAC is inevitable

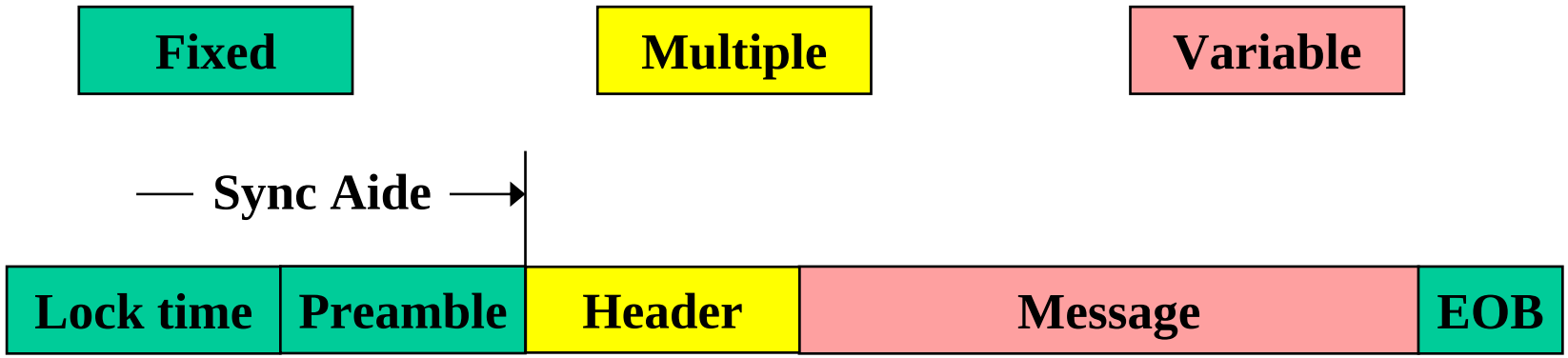
128bit Multi Preambles

False Alarm & False Dismissal Probability of 128bit preamble

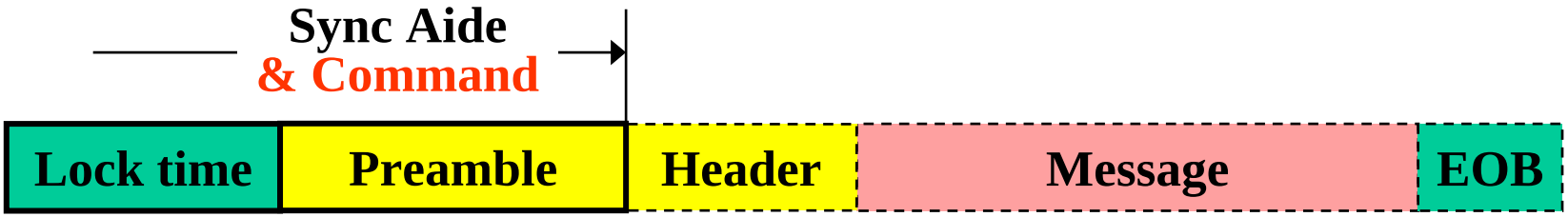


64bit is not enough but 128 bit is high enough ; so we suggest multi Preamble

Multiple Preamble Structure



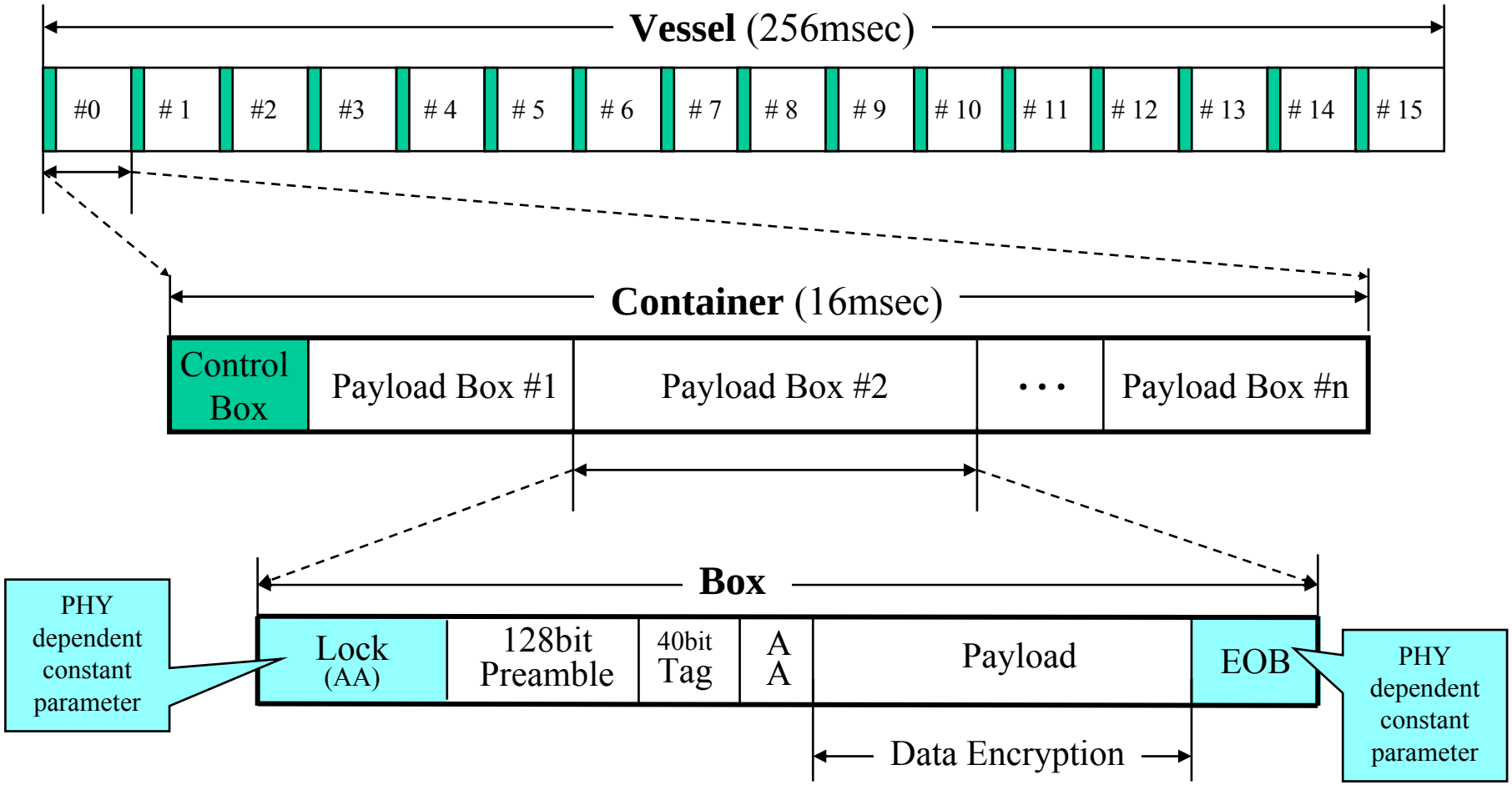
Conventional Frame Structure



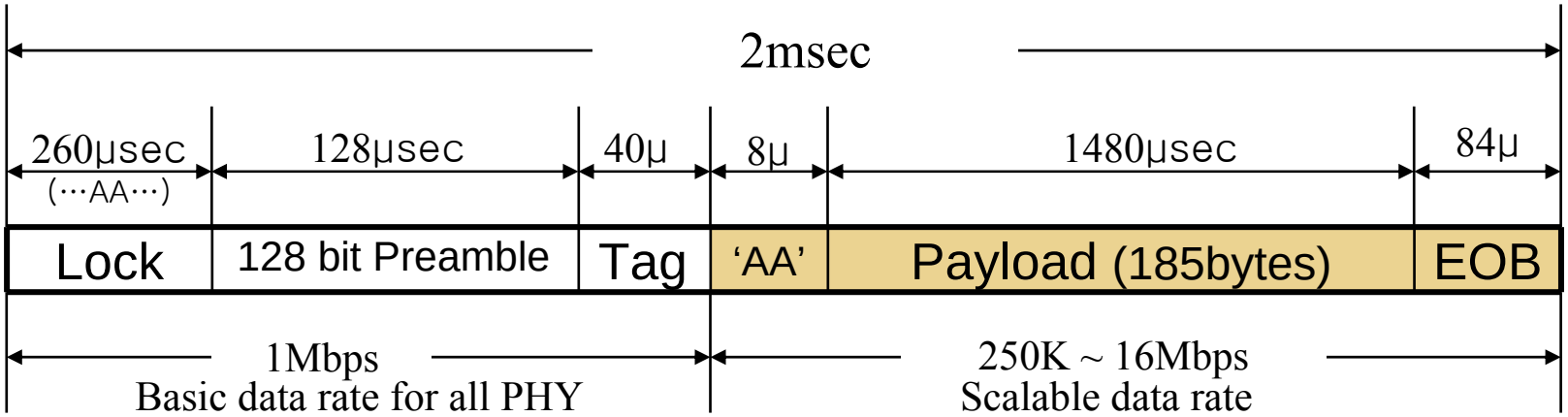
Suggested Frame Structure

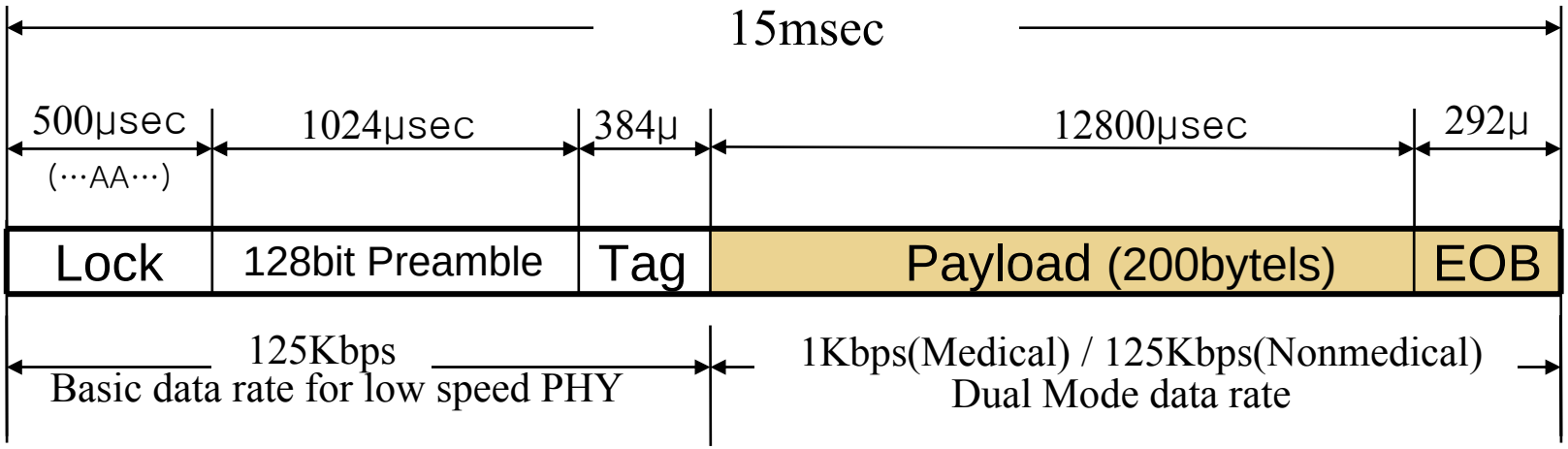
Multiple Preamble contains short message

Basic Components of PicoCast MAC

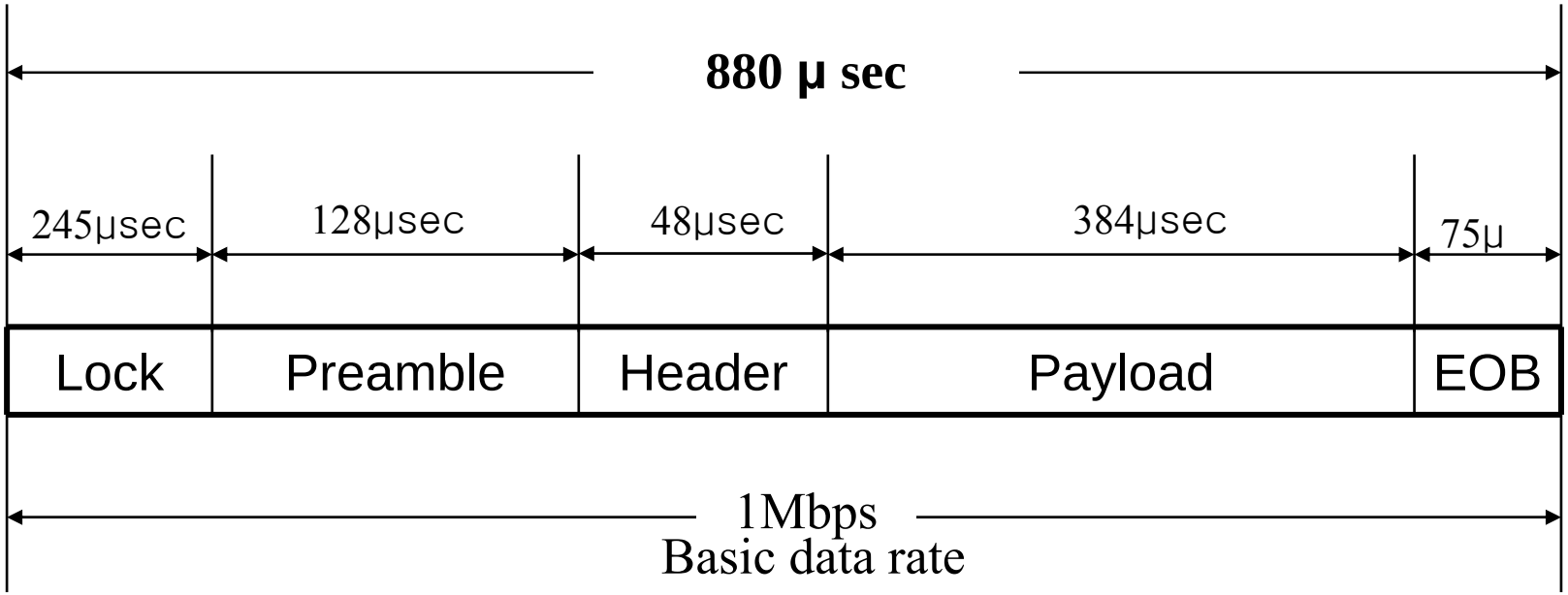


Example of Box Structure for different PHY



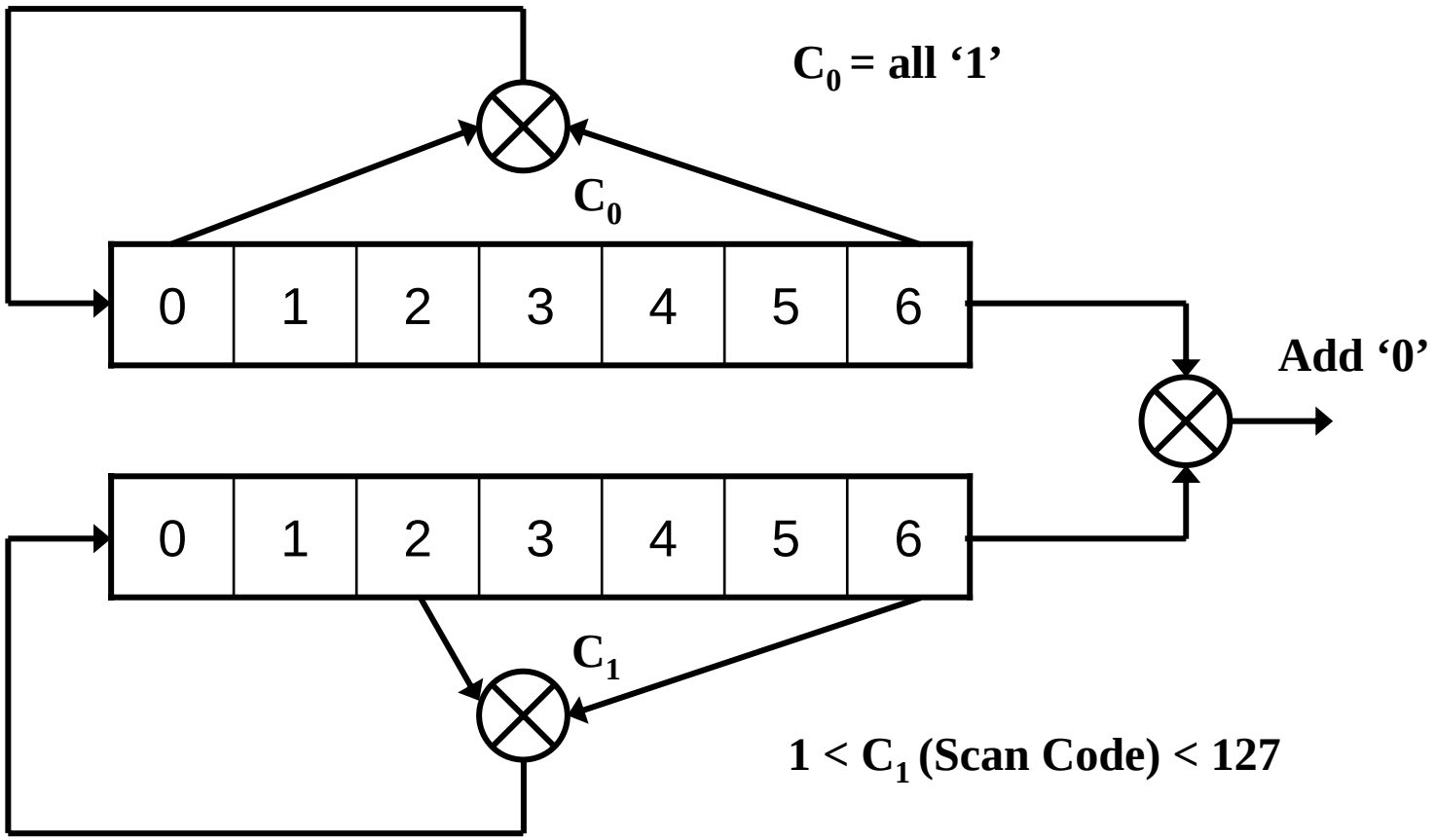


Example of Control box structure



- Preamble : 128μsec : 128bits
- Header : 48μsec : 4Bytes + CRC16
- Payload : 384μsec : 46Bytes + CRC16

Multiple Preamble Generator

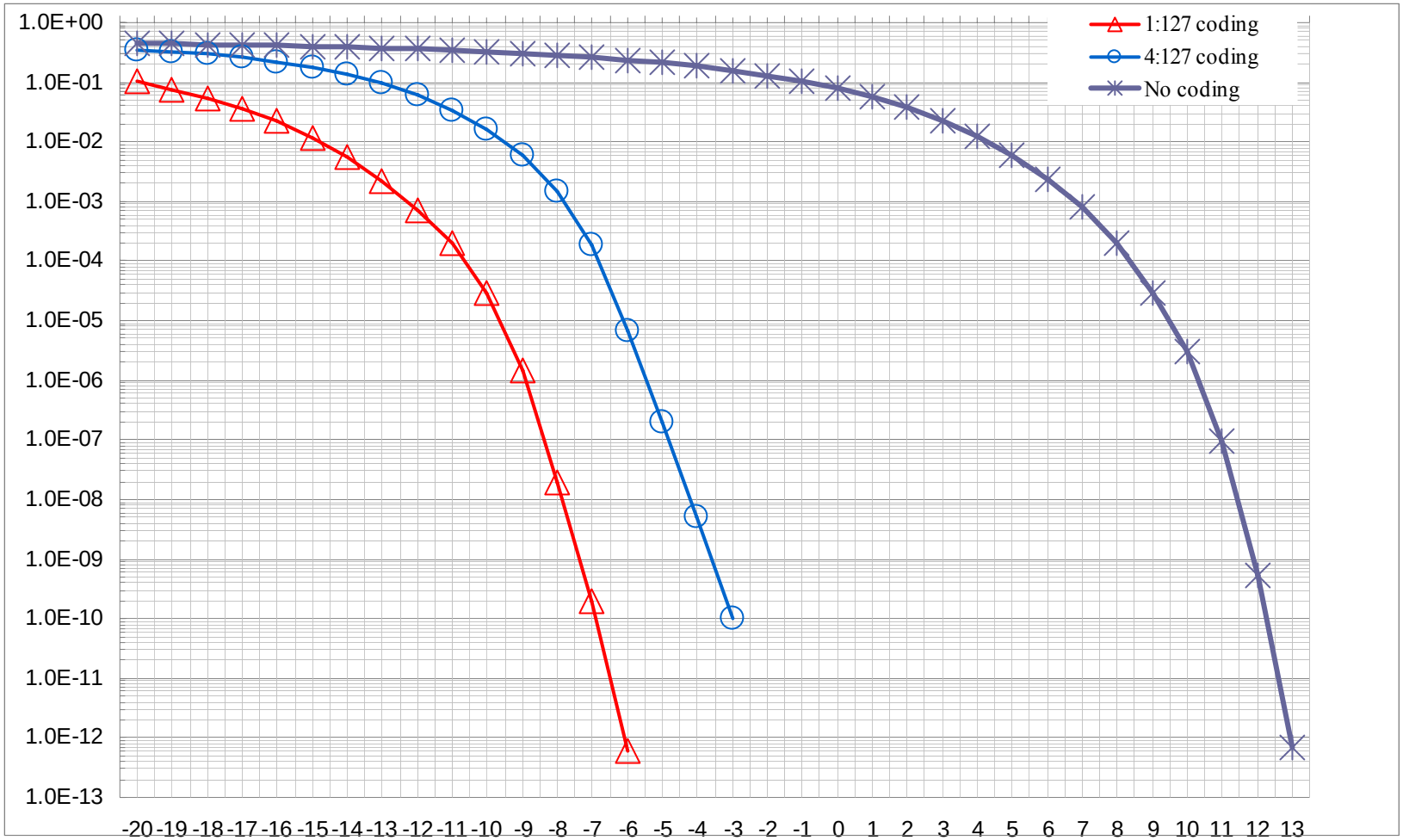


127bit Gold code Generation and '0' insertion

Multiple Preamble Usage

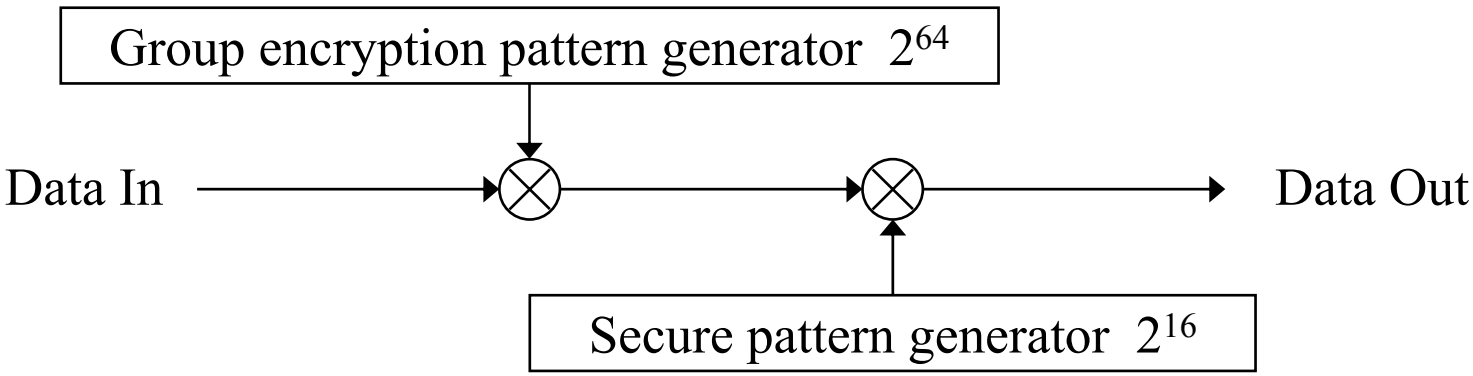
C_1	Remarks
1 ~ 8 (8)	General Box purpose (Control, Payload)
9 ~ 12 (4)	Hierarchy Beacon Box for synchronization
13 ~ 16 (4)	Pairing Box (Fast Beacon Box)
17 ~ 18 (2)	Sounding Box
19	Reliable Medical 1bit/symbol data transmit
20 ~ 35 (16)	Reliable Medical 4bit/symbol data transmit ※ would be substituted by the best code set after simulation study.
36 ~ 41 (16)	Hands over for the local broadcasting
42 ~ 49 (8)	Define Multi-RF to indicate sequence order
50 ~ 127 (except 119)	TBD ; waiting for MICS or special PHY applications
119	**Emergency**

Performance of 128bit Preamble Symbol

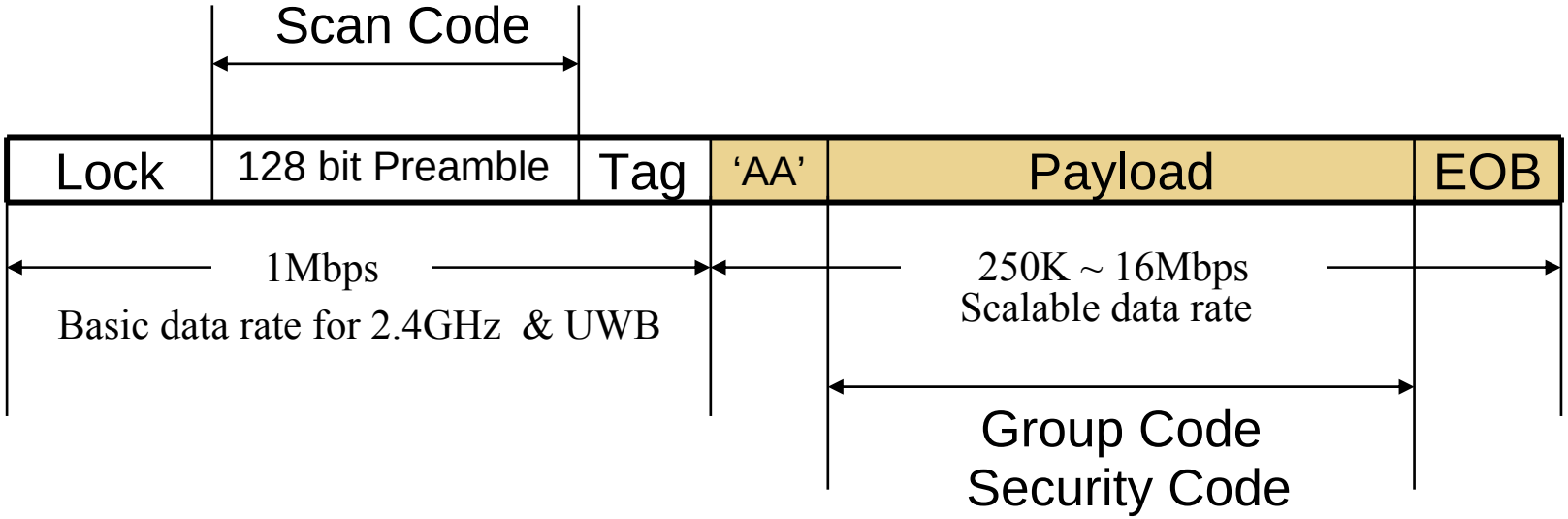


Code Types

Type	Bit	Description
Scan Code	7	C1, To generate multiple preamble
Group Code	64	To generate group encryption pattern
Security Code	16	To protect secure data among group
ID	64	Assigned to every device as serial number

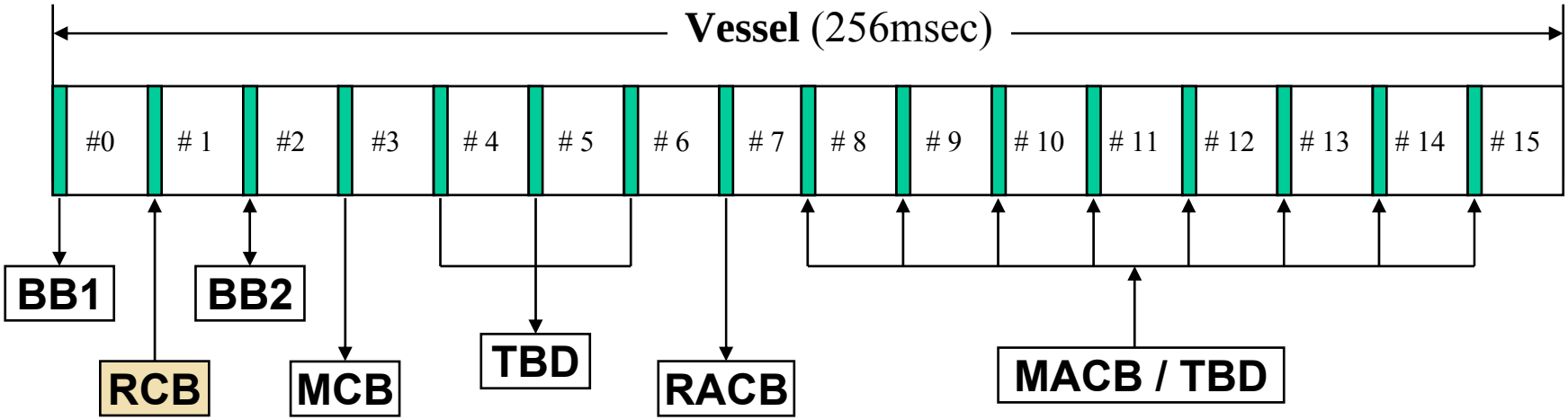


Code application for Box contents



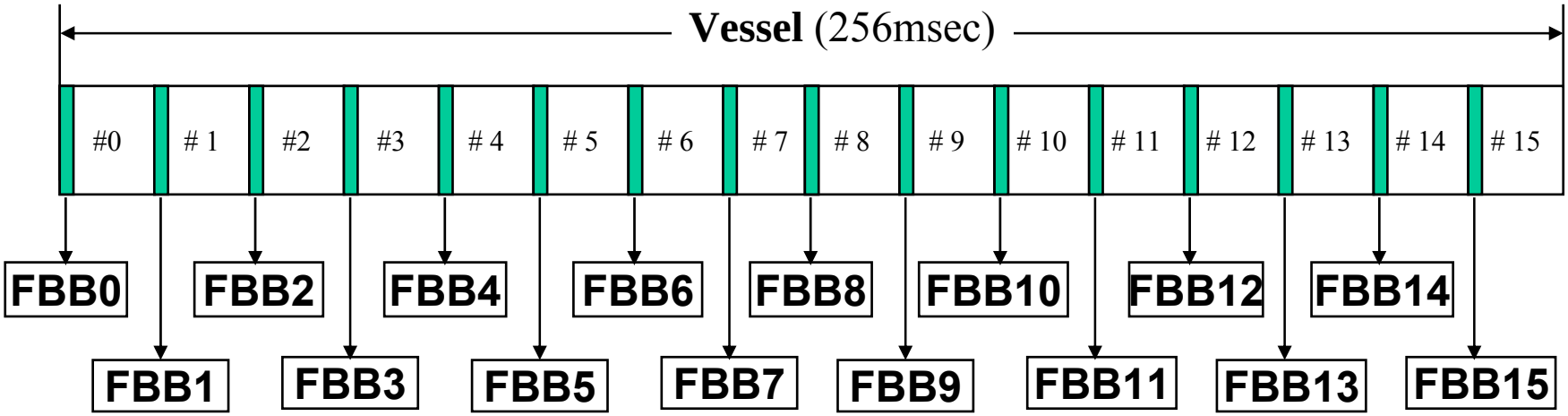
- **Group Code is used for payload data only.**
  - **Different group can not communicate each other**
  - **64bit ID of Master can be used as Group code**
- **Security Code is set as '0' for normal condition**

Control Box for normal Vessel



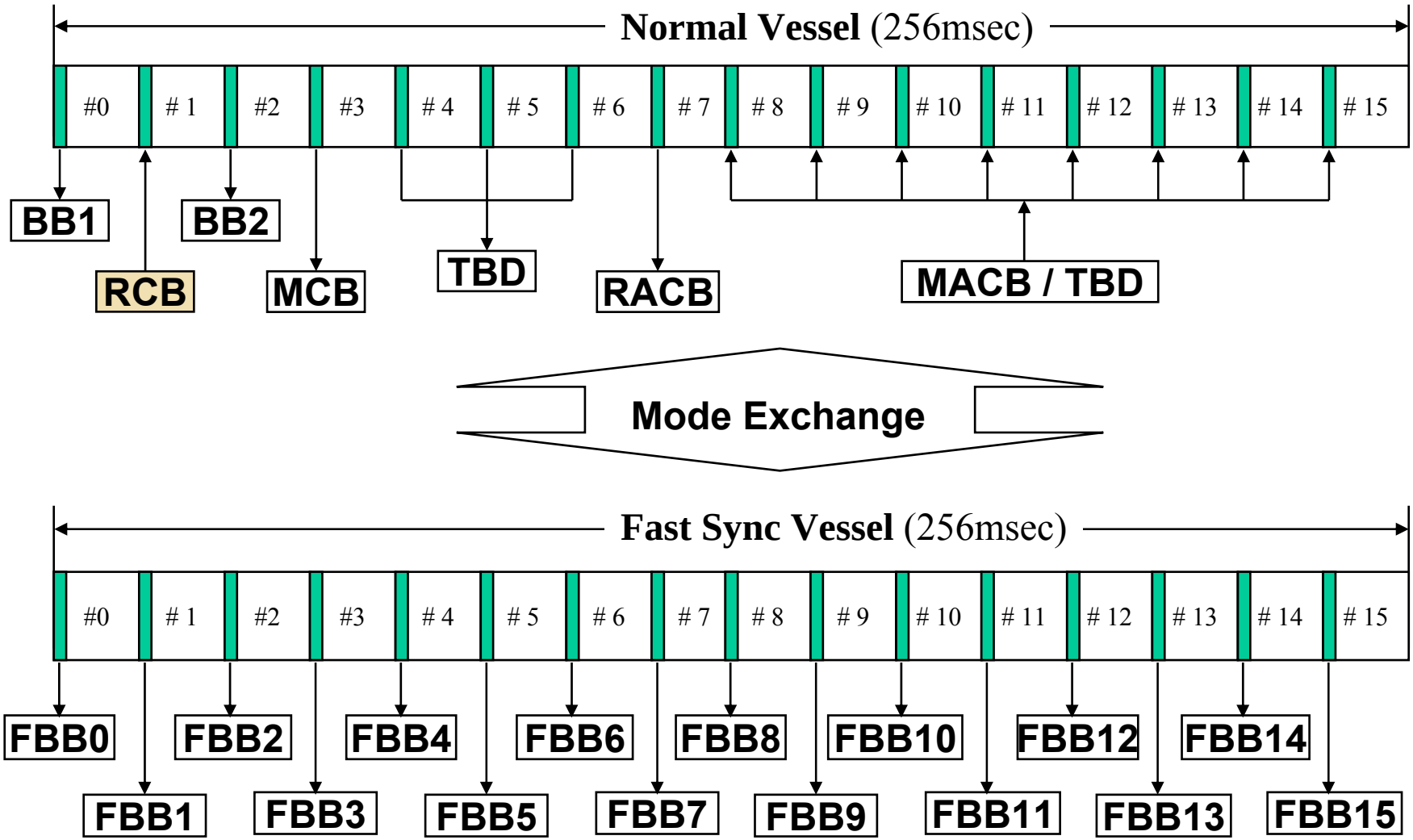
- BB1 : Beacon Box 1, (Master Tx only)
- BB2 : Beacon Box 2, (Master Tx, Rx Alternate for Sync Relay)
- RCB : Request Control Box ; Contention permitted mode
- MCB : Master Control Box
- RACB : RCB Acknowledge Control Box
- MACB : MCB Acknowledge Control Box

Control Box for fast sync Vessel

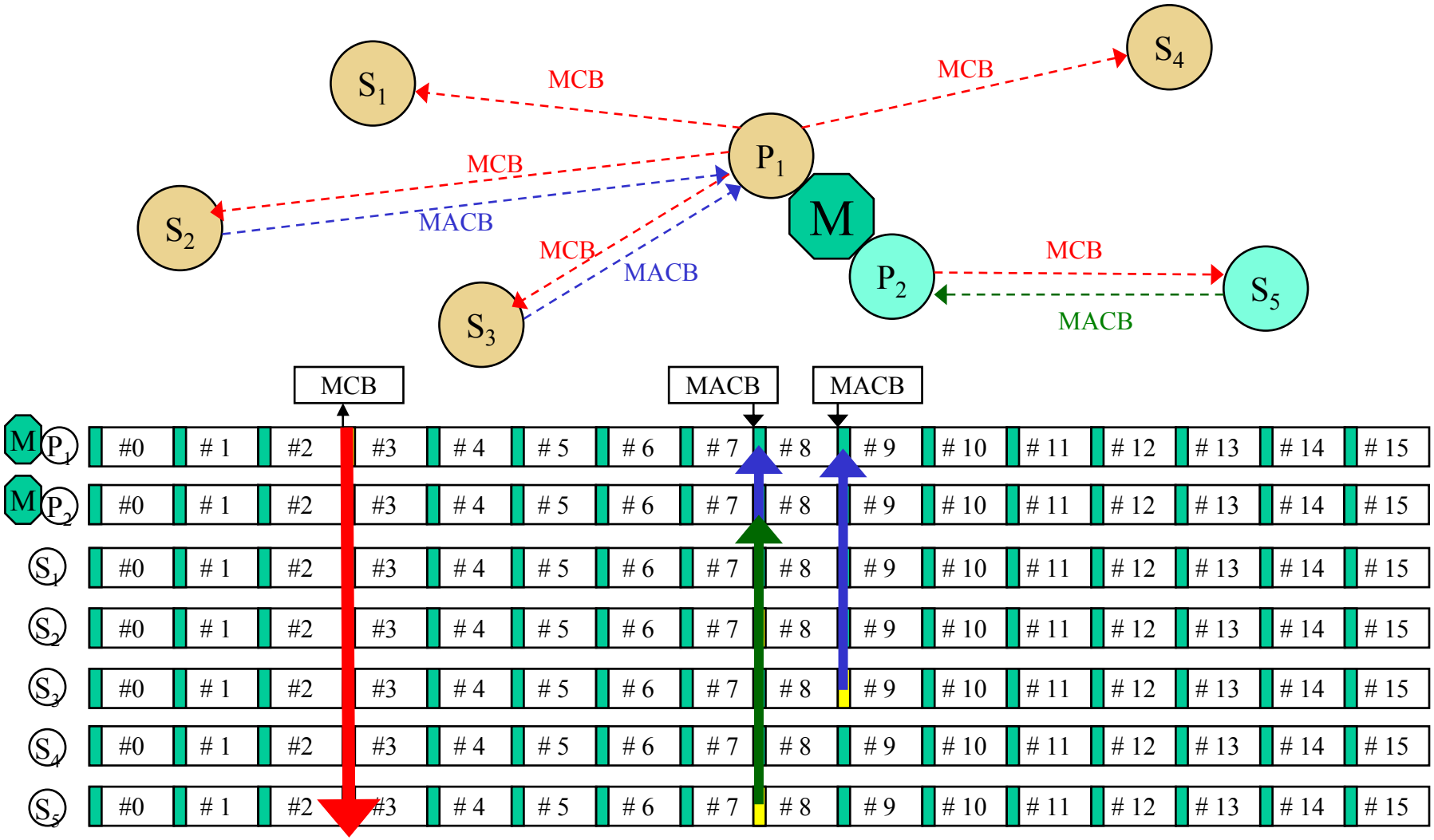


- FBB : Fast Beacon Box
- 16 frequencies are used for synchronization.
- FBB use special preamble assigned for fast paring
- Normally fast paring is done within 256msec
- Within 1sec paring requirement is realizable

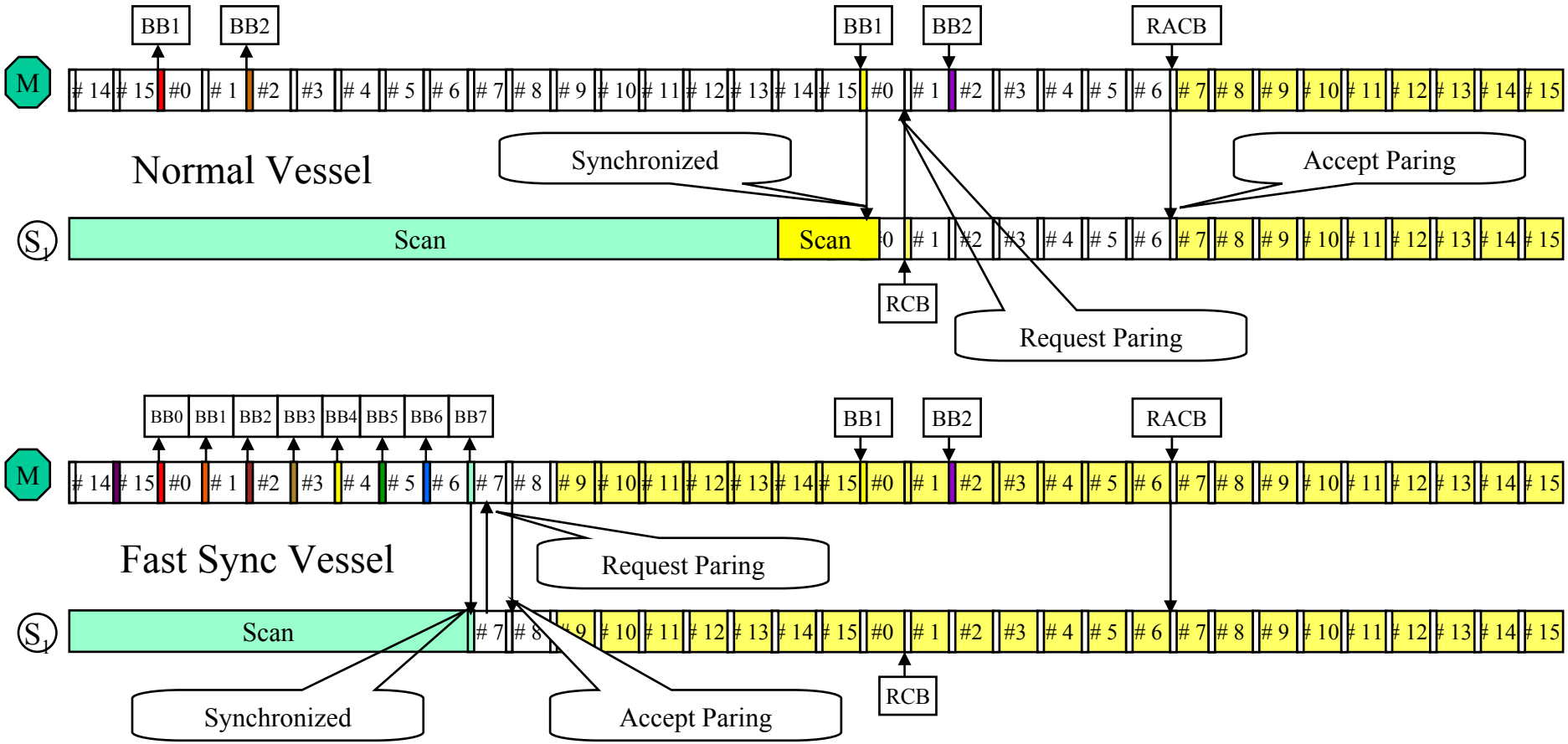
Vessel Mode Change



MCB Operation Example

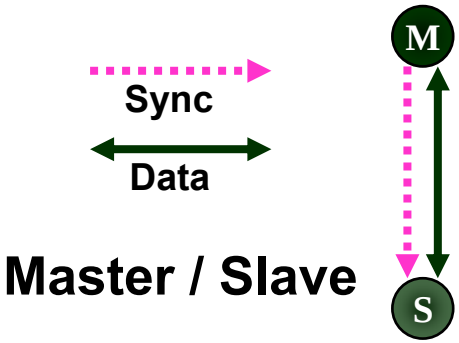


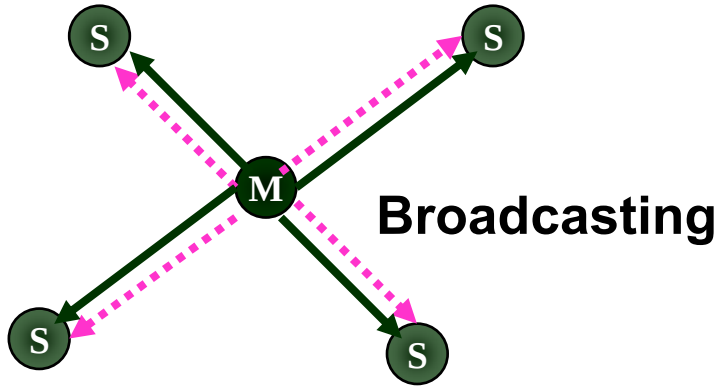
Paring Process

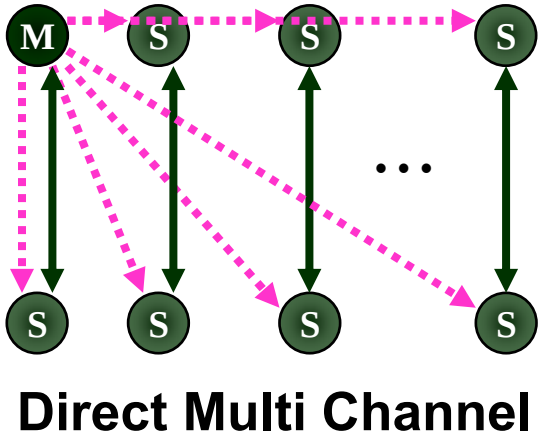


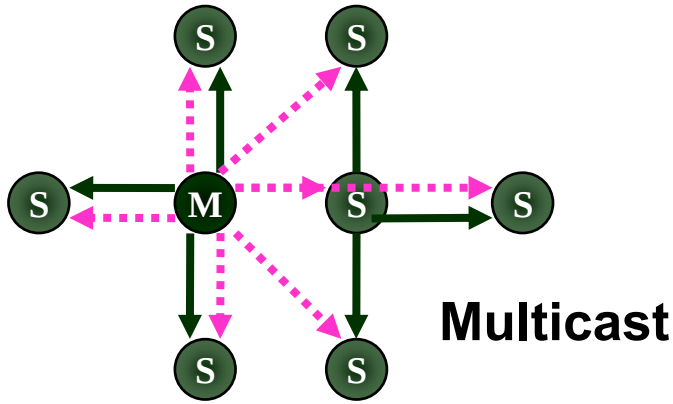
- **Full scan time of normal vessel is 2sec.**
- **That of fast sync vessel is only 256msec**

Protocol Topologies









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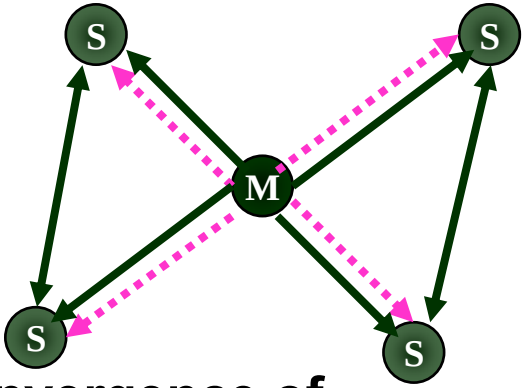
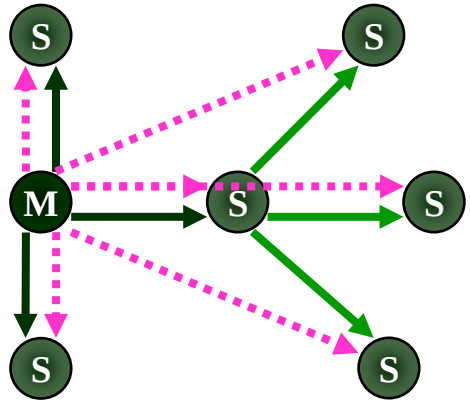
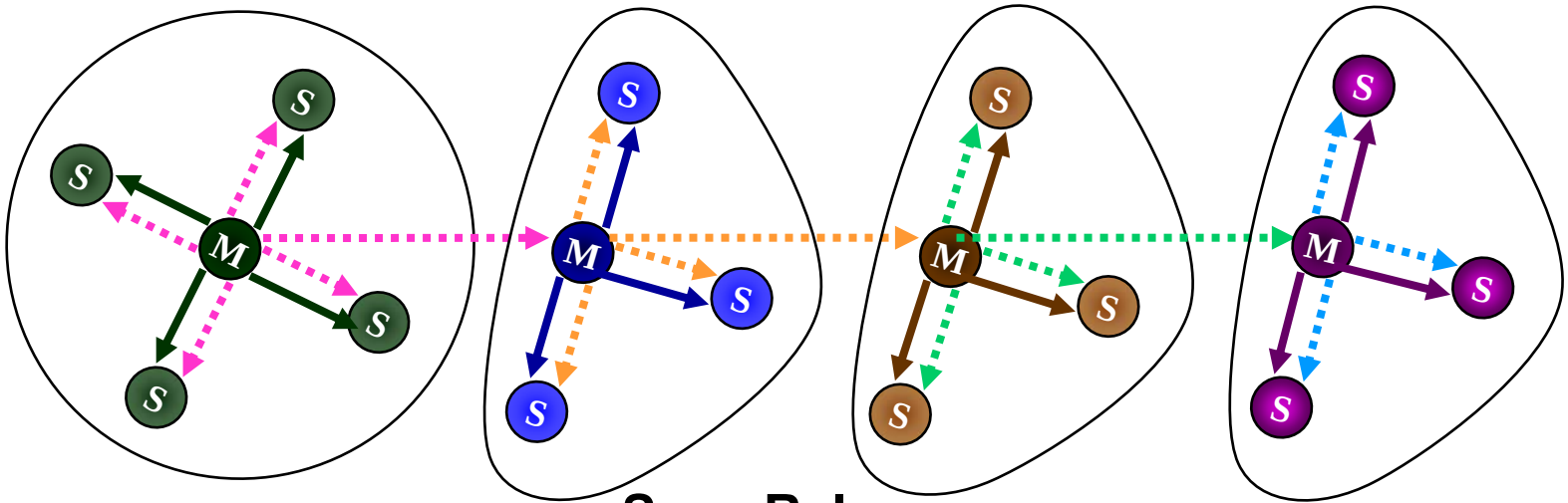


Convergence of Broadcasting & Communication

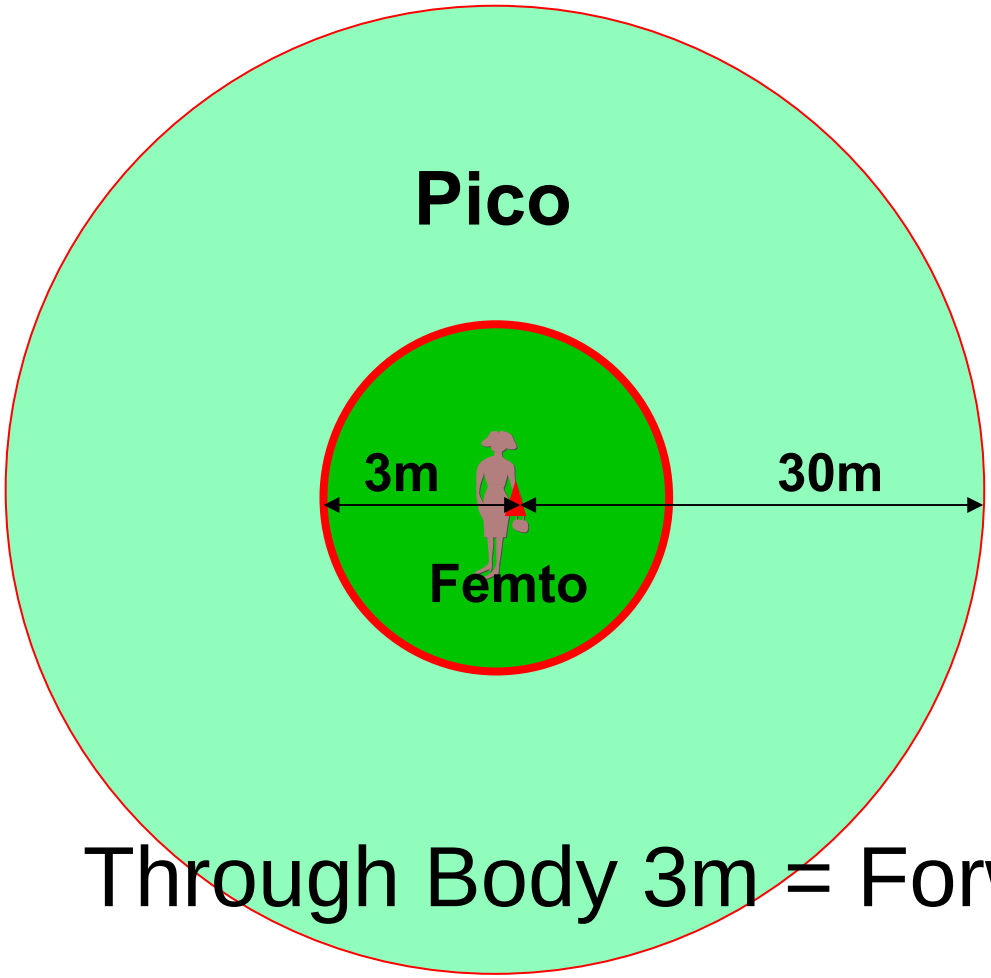


Broadcast Relay with Single Master



Sync Relay

Additional Considerations for WBAN



- Open PHY Interface
- Power Control
- Smooth Sliding Sync
- Role Exchange
- QoS Check
- Sounding
- Emergency Flooding
- Roaming / Hand-over
- Sensor Mesh Relay

Through Body 3m = Forward Body 30m

Conclusion

- PicoCast protocol is submitted as a single MAC for multiple PHYs.
  - Container concept to reject mutual interference and converge various services
  - Multi preamble to enhance synchronization probability & for special purposes
  - Hierarchical sync & code structure for scalable & self organizing system
  - Common channel signaling based on vessel structure for various service
  - Welcome Multiple preamble usage for special purpose like medical application
- Suggested MAC can be used for 5G mobile communication, too.
  - WBAN body master & mobile femto-cell have almost same structure
  - In the future, the cell size of 5G will becomes femto-cell because of capacity
  - User oriented broadcasting and communication convergence is possible
  - White space devise requirements would be satisfied with PicoCast protocol
- System evaluation tool and S/W driver can be supplied to PHY partners.
  - Technical sheet of PHY interface can be supplied to whom want to be partner
  - Evaluation board to test interoperability can be supplied as project base
  - Stable & reliable S/W library for single RF is possible now
  - S/W library for multiple PHYs will be open within the end of this year