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**Re:** [Considerations on system design for PHY and MAC in 802.15.4m]

**Abstract:** [This document discusses the general overview of design consideration in 802.15.4m from the perspective of regulations, network, PHY and MAC design ]

**Purpose:** [To provide an clear direction for the technical design of 802.15.4m]

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# High Level Summary

- This document presents the technical design considerations for IEEE 802.15.4m Low-Rate Wireless Personal Area Networks (LR-WPAN) operating in TV White Space (TVWS)
- Potential LR-WPAN usage model and TVWS regulations are influential factors determining the system design of 802.15.4m, and are introduced briefly in this document
- Technical design considerations including channelization, network architecture, PHY layer design and MAC layer design necessary to regulatorily-enable and technically-optimize 802.15.4m system in TVWS are discussed
- Focus is given on reusing legacy 802.15.4-2011 functionalities where possible, and adding new ones where necessary, to specify a practical LR-WPAN operating in TVWS

# Outline

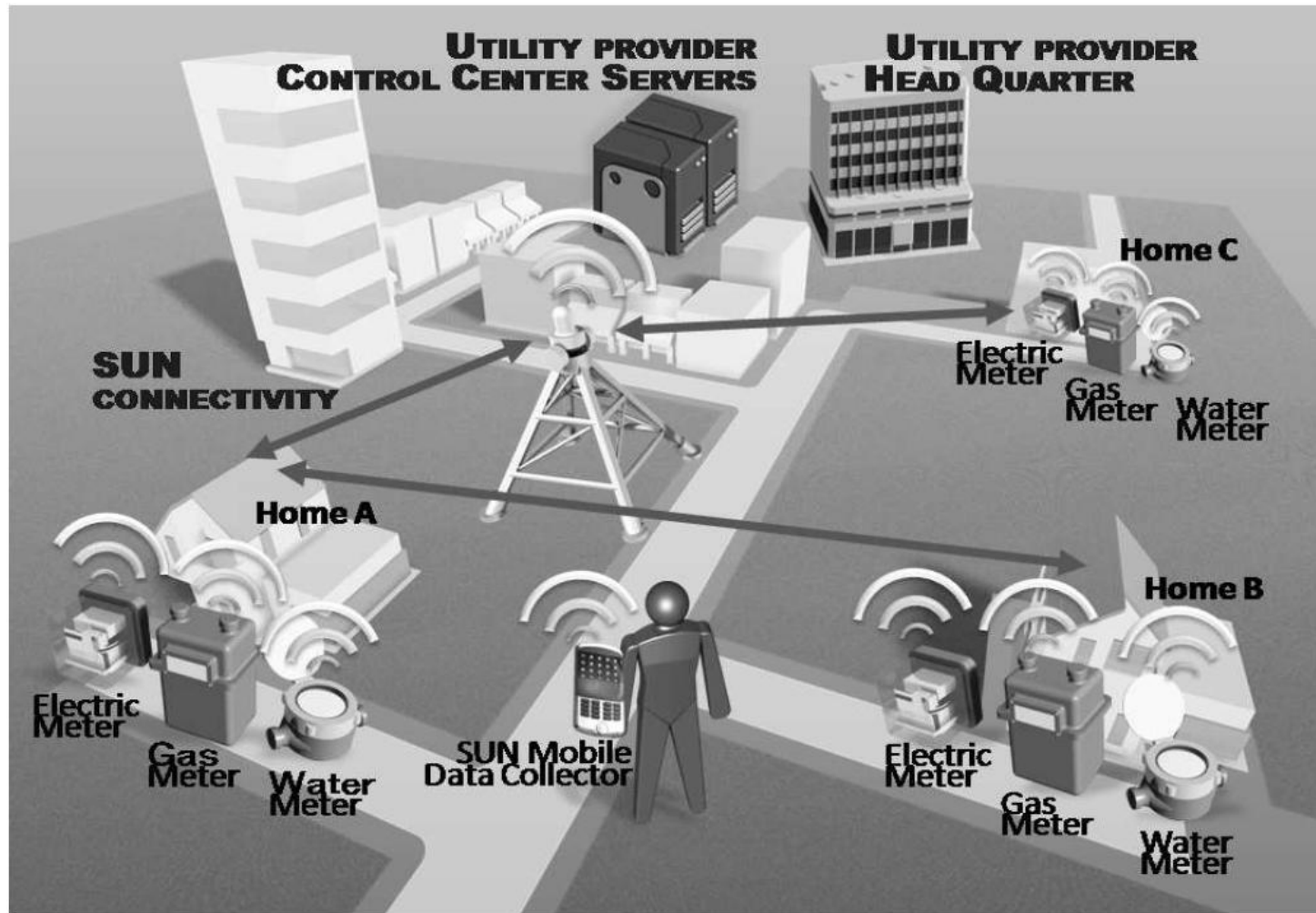
- Usage Models
- TVWS Regulations
- Channelization
- Network Topology
- MAC Layer Design

# Usage Models

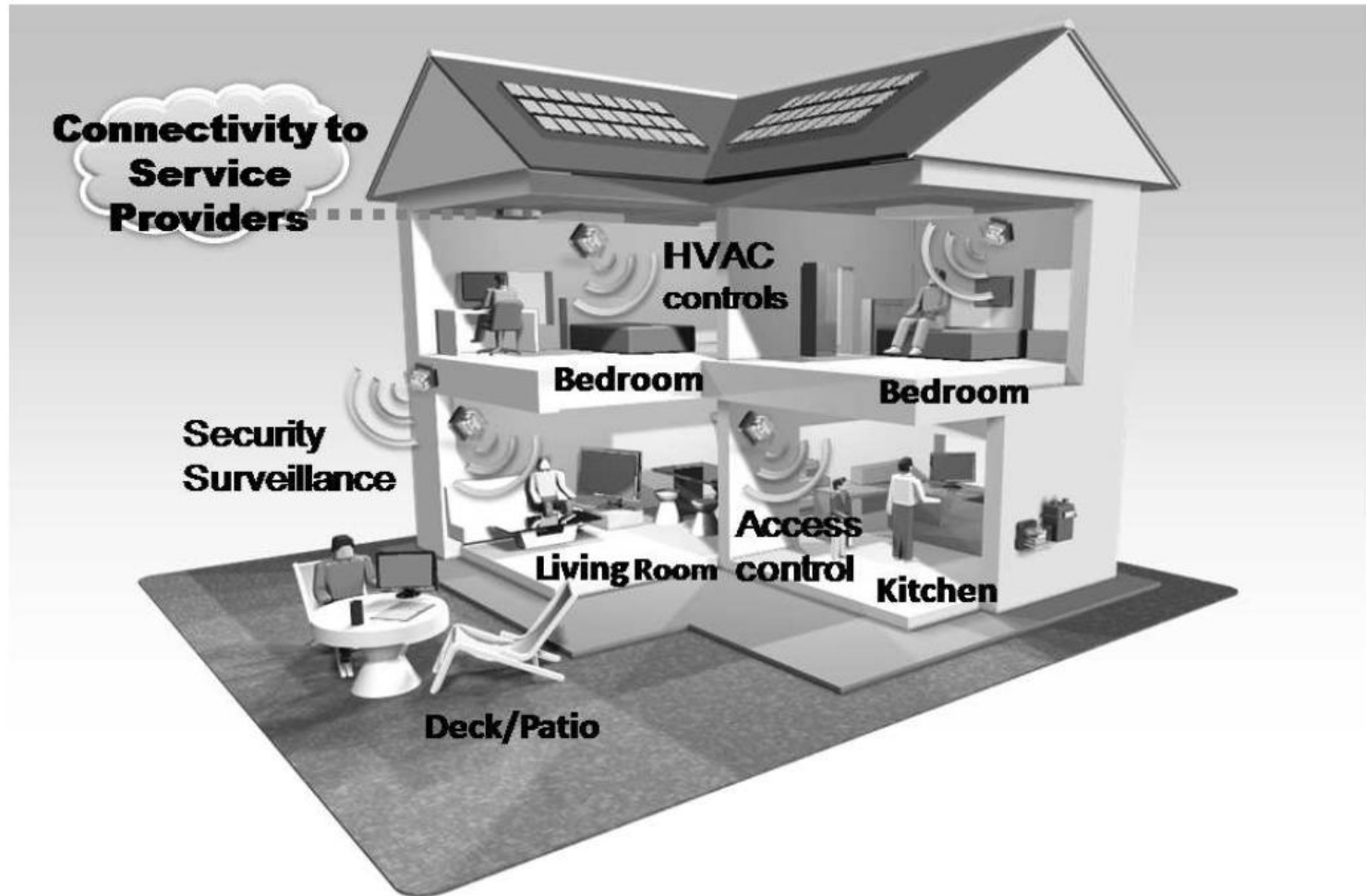
# Foreword

- Usage models identified for 802.15.4 operating in TVWS are typically, but no limited to
  - Smart utility networks (SUN)
  - Sensor networks
  - Machine-to-machine communication networks
  - Device command and control applications
- Other additional potential usage models will be proposed along with 802.15.4m progress
- Following slides illustrates some example scenarios of the identified usage models

# Example 1: Smart Utility Networks



# Example 2: Sensor Networks



# TVWS Regulations



# Foreword

- Regulatory organizations outline governing rules for unlicensed use of TVWS
- Regulators active in the TVWS arena: US FCC, UK OFCOM, Canadian Industry Canada, European CEPT, Japanese MIC, Singaporean IDA and global ITU
- FCC has a published set of governing rules sufficient for implementation guidance
- OFCOM and Canada Industry are in the process of publishing respective governing rules
- CEPT, MIC and ITU are in the process of reviewing the possibility of TVWS
- IDA is providing TVWS field trials for management and interference assessment

# TVWS Regulations Overview

Regulatory Domains	FCC, USA	OFCOM, UK	Industry Canada, Canada	CEPT ECC, Europe
Status	Published	Under consideration	Under consideration	Under consideration
TV Channel-ization	6 MHz	8 MHz	6 MHz	8 MHz
Available TV Channels	Ch2 to Ch4: 54 to 72 MHz Ch5 to Ch6: 76 to 88 MHz Ch7 to Ch13: 174 to 216 MHz Ch14 to Ch51: 470 to 698 MHz	Ch21 to Ch60: 470 and 790 MHz	Ch2 to Ch4: 54 to 72 MHz Ch5 to Ch6: 76 to 88 MHz Ch7 to Ch13: 174 to 216 MHz Ch14 to Ch51: 470 to 698 MHz	470 to 790 MHz
Device Type	Fixed device (FD) Personal/portable device (PPD) Mode II PPD Mode I PPD Sensing-only device (SOD)	Master device (MD) Slave device (SD)	Fixed WSD (FWSD) Mobile WSD (MWSD) Mode II  MWSD Mode I	Master device (MD) Slave device (SD)
TX Power	FD: 4W PPD: 100mW PPD SOD: 50mW FD disallowed in first adjacent channel PPD: 40mW (adj. channel)	DB informs the allowable transmit power	FWSD: 4W MWSD: 100mW MWSD: 40mW (adj. channel)	DB informs the allowable transmit power
Access Rules	FD: Ch2, Ch5 to Ch35, Ch39 to Ch51 PPD: Ch21 to Ch35, Ch39 to Ch51	MD and SD: Ch21 to Ch30 and Ch39 to Ch60	FWSD and MWSD: Ch2 to Ch36 and Ch38 to Ch51	–
DB Access	FD: once/day PPD Mode II: once/day, every 100m relocation PPD Mode I: not required PPD SOD: not required PPD Mode II may access DB via other PPD Mode II	MD: required SD: not required DB informs available channels and information time validity	MWSD: required FWSD: required FWSD Mode II may access DB via other FWSD Mode II	DB informs available channels and information time validity
Geo-location	FD: accuracy 50m PPD Mode II: accuracy 50m, re-establish location every 60s PPD Mode I: not required PPD SOD: not required	MD: accuracy 100m SD: not required	MWSD: required FWSD Mode II: required FWSD Mode I: not required	MD: required SD: not required
Spectrum Sensing	PPD SOD: required	DB informs whether sensing is required	–	DB informs whether sensing is required
Additional Notes	Contact Verification Signal required by PPD Mode I every 60s	–	The channels bands are currently being shared with low power apparatus (LPA) and remote rural broadband systems (RRBS)	–

# TVWS Regulations Extracts

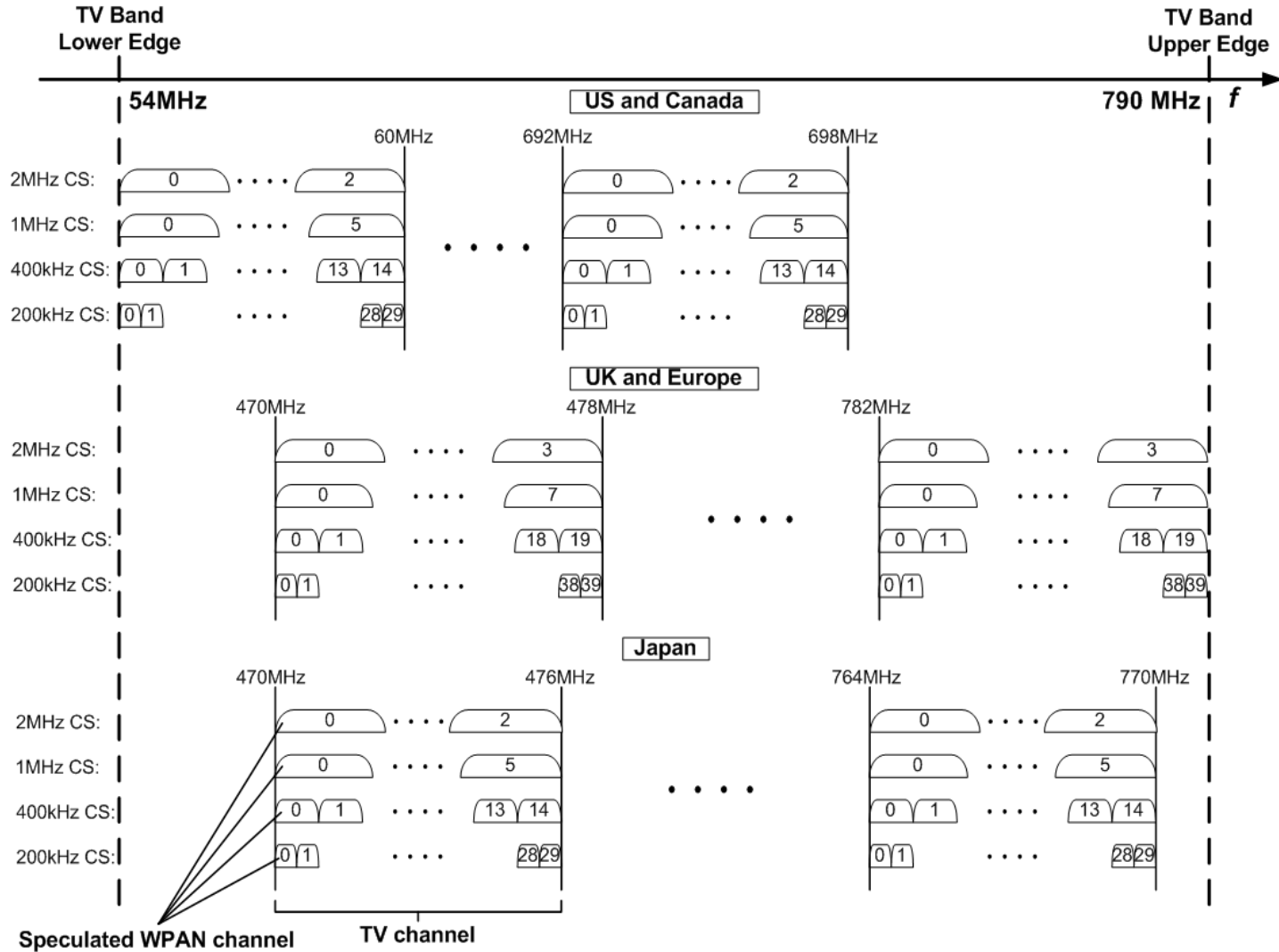
- TV band 54-790 MHz globally
  - 6 to 8 MHz channel width
- Master-slave architecture
  - Possibility for peer-to-peer connectivity
- Device categorization
- Detection of incumbent users
  - Geo-location database (GDB)
  - Spectrum sensing (optional)
- Device-to-GDB connectivity
  - Directly
  - Through a proxy server
- Protection to incumbent users
  - Channel access control
  - Power management

# Channelization

# Foreword

- Lower edge for global TV band is 54 MHz and upper edge is 790 MHz
- TV channels are typically 6 to 8 MHz wide
- 802.15.4 channels are generally but not limited to 200, 400, 1000 and 2000 kHz
  - Refer to Section *PHY Layer Design*
- Effectively, one TV channel is capable of accommodating multiple 802.15.4m channels
- In 802.15.4m channelization, care should be taken on
  - Regulatory-domain-specific blacked-out TV channels
  - Regulatory TVWS transmit spectrum mask

# TV Channels to LR-WPAN Channels



# Network Topology

# Foreword

- Network architecture required by most TVWS regulations is the master-slave architecture
- Conventional 802.15.4 network architecture and device is generally able to support TVWS regulatory requirements
  - 802.15.4 device types can be mapped accurately to regulatory TVBDs
  - 802.15.4 star and tree network topology can be effectively compliant to the regulatory required master-slave architecture
  - 802.15.4 is able to support peer-to-peer topology (specific technical details are not covered in 802.15.4-2011)
- Major fraction of 802.15.4 architecture and components can be reused
- Several potential modifications/additions
  - Direct device-to-device communication in star network
  - Technical details for direct peer-to-peer connectivity mechanism



# 802.15.4 Network Topology

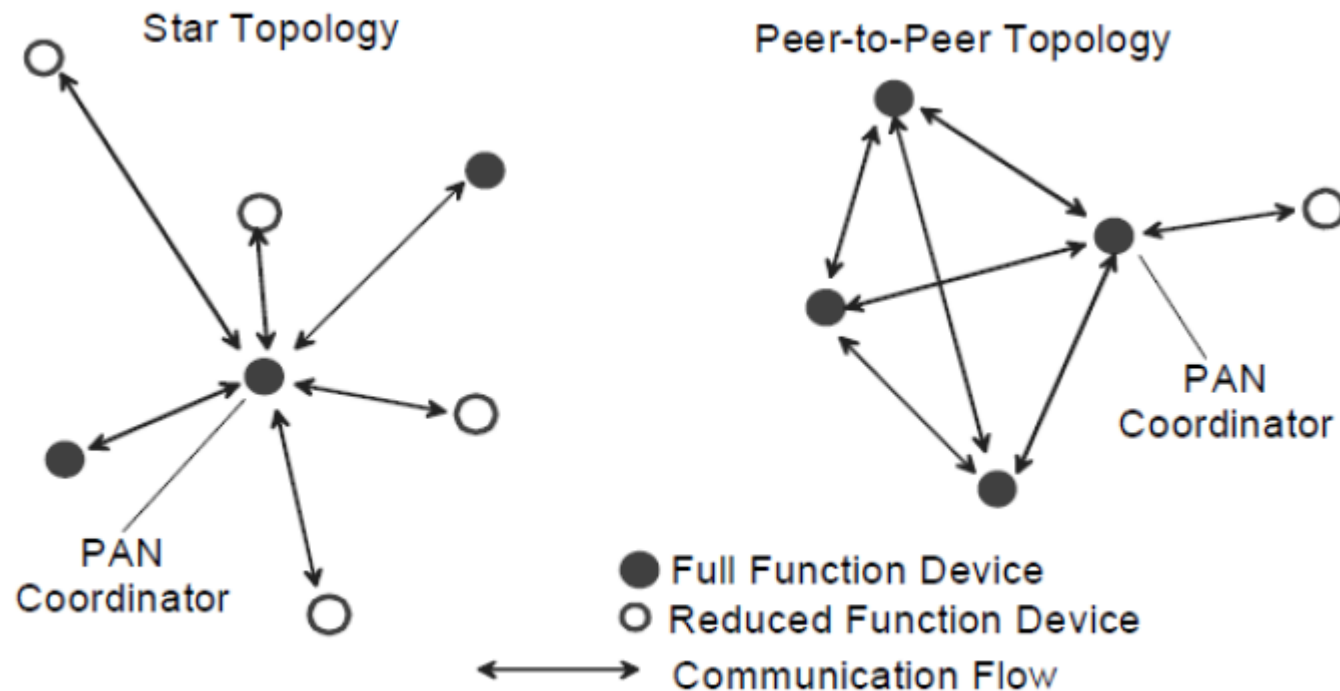
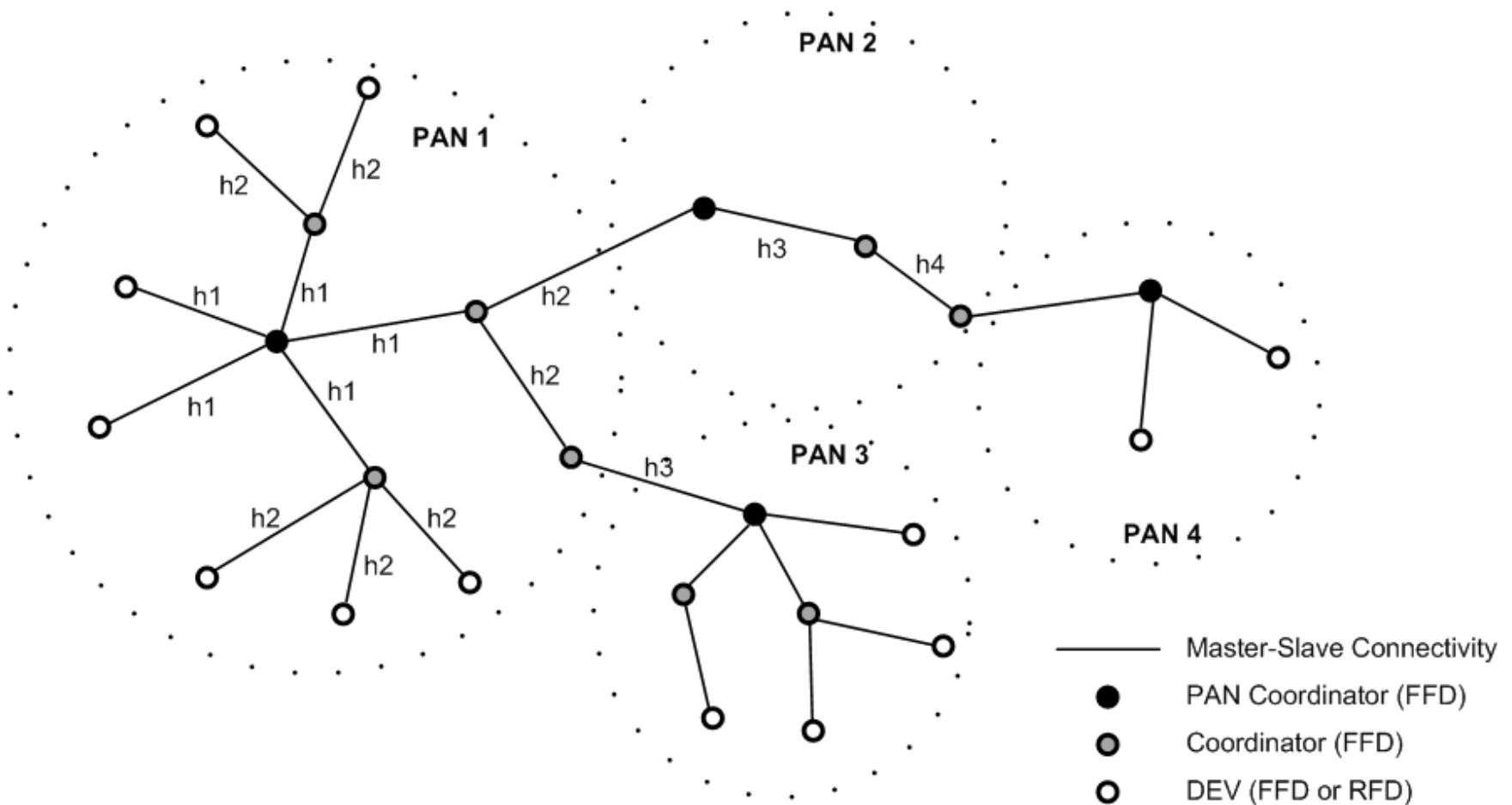


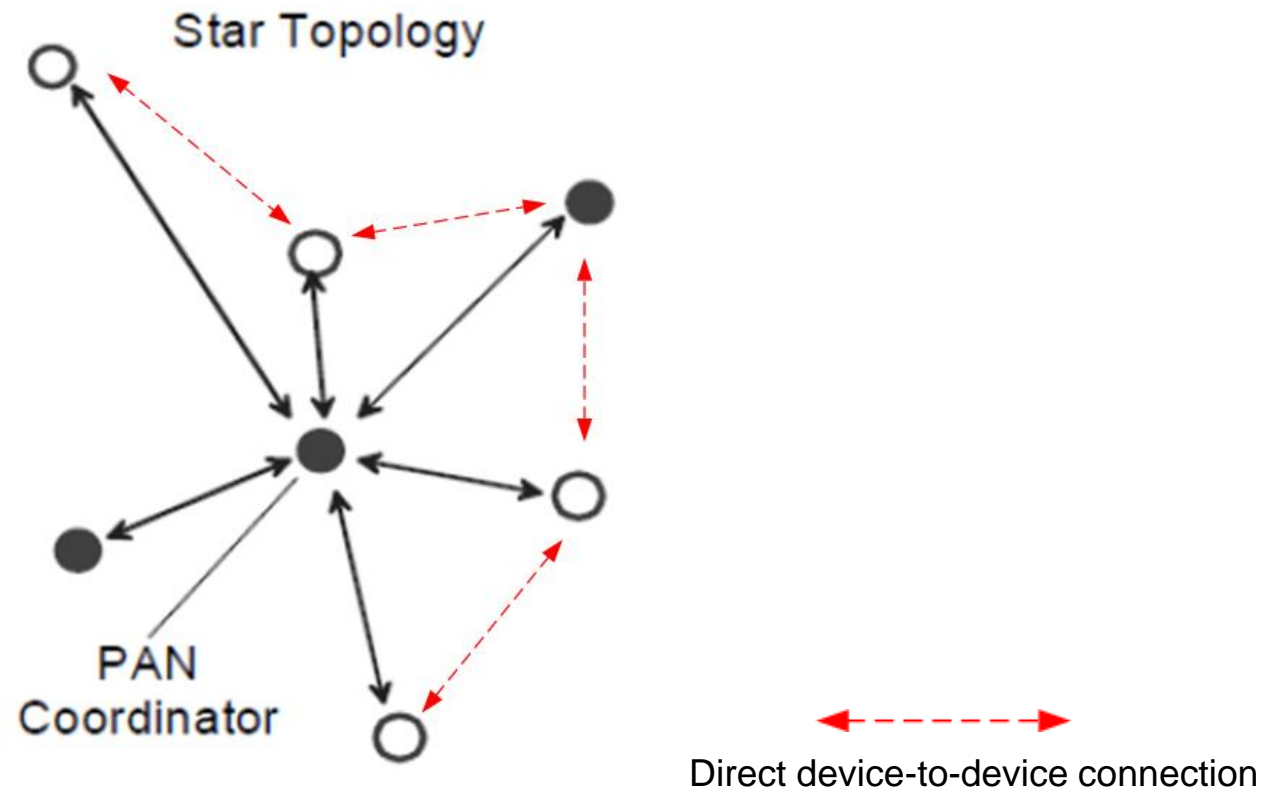
Figure 1—Star and peer-to-peer topology examples

# Cluster Tree Network – A Special Case



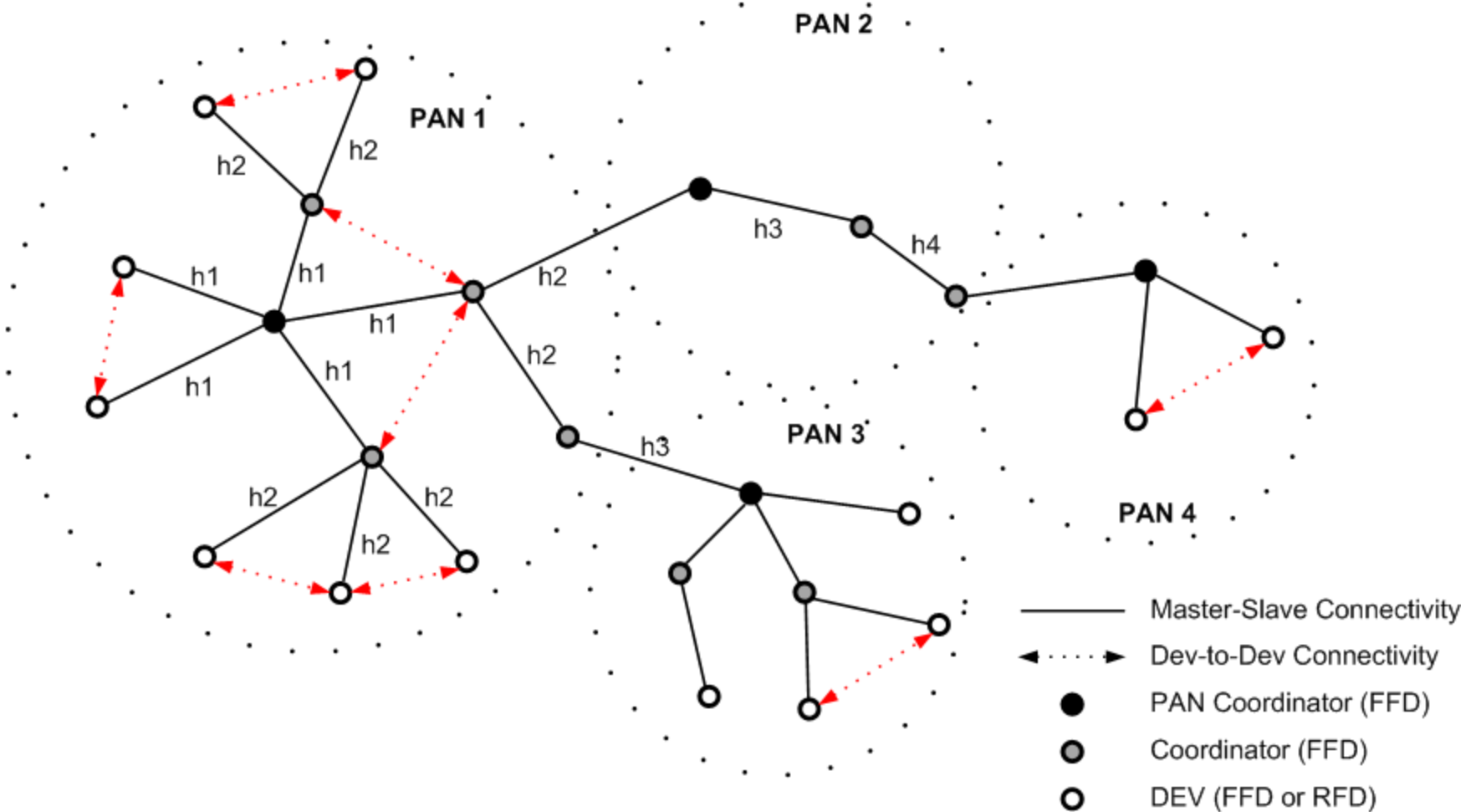
# Potential 802.15.4m Amendments

- Direct device-to-device communication in Star network



# Potential 802.15.4m Amendments (cont.)

- Direct peer-to-peer connectivity mechanism



# MAC Layer Design

# Foreword

- Major parts of the 802.15.4 MAC layer design can be reused in 802.15.4m
- In order to equip 802.15.4m system with the capability to comply with TVWS regulatory requirements, the below MAC functionalities are added:
  - TVWS operation enabling mechanism
  - Dynamic frequency band switching mechanism
  - Scalable energy consumption mechanism

# TVWS Operation Enabling

- TVWS regulatory requirements (employing GDB)
  - master device obtain TVWS access permission from GDB directly or through a proxy
  - master device enables slave device
  - Slave device operates in TVWS
  - Master device may need to update the availability of TVWS periodically
- 802.15.4m task to comply with regulatory requirements
  - Reuse where possible, MAC functionalities in 802.15.4 to comply with the operation enabling requirement
  - Add **only where necessary**, new MAC functionalities
- Modifications or additions should be performed on top of 802.15.4 protocols, frames and interface

# Dynamic Frequency Band Switching

- TVWS offers encouraging spectrum resources for LR-WPAN
  - Increase number of supported users
  - Improve quality of service
- However, regulatory conditions in many countries are still in progress and may remain so for a relatively long period in the future
- Therefore, it is important to provide to 802.15.4m implementers a mechanism to facilitate switching of frequency bands from TVWS to respective conventional frequency bands
  - Example: TVWS back to US Smart Utility Networks 902-928 MHz and vice versa
- Main advantages are
  - improving compatibility among devices in different regulatory domains
  - providing diversity for performance improvement
  - reduce the risk of relying on one particular band or exploring a newly regulated band



# Scalable Energy Consumption

- A big fraction of the LR-WPAN identified usage models employ network topologies of star/tree and peer-to-peer connectivity.
- Besides, many of these usage models require device battery lifespan up to several years
- In a star/tree topology, master devices are mains-powered and slave devices are battery-powered
- In a peer-to-peer topology, all devices are expected to be battery-powered
- This suggests that a flexible energy consumption model is necessary in 802.15.4m
- The scalable energy consumption mechanism is designed based on manipulating the radio operation time (i.e. channel scanning and transmission for control and data communication) as compared to sleep time
- The energy consumption mechanism should also take into consideration different demands for implementing star/tree and peer-to-peer topologies

# Conclusion

- This document presents the technical design considerations for IEEE 802.15.4m LR-WPAN operating in TVWS
- It is the intention of the authors to invite active discussions on these design considerations to achieve further refinement and enrichment
- These design considerations are expected to serve as the guidance to the system design of IEEE 802.15.4m