Wireless Coexistence: Principles and Practices

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FCC
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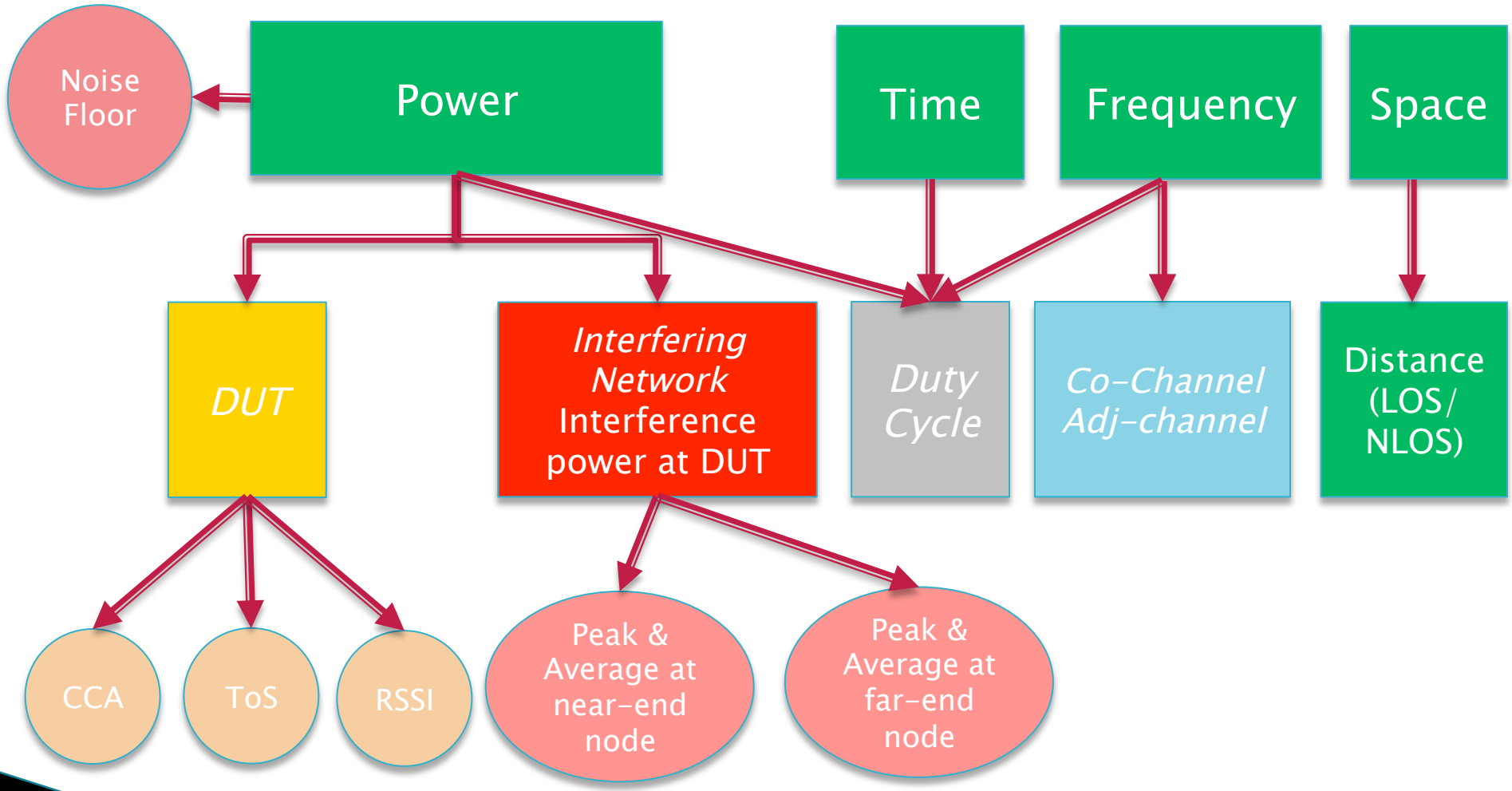
Outline:

- Motivation and Objective
- Wireless Coexistence Factors
  - Power/Space
  - Frequency
  - Time
- Coexistence Testing Protocol
- Case Studies
  - Conducted
  - Radiated Open Environment (OU)
- Repeatability and Reproducibility Check
- Coexistence Log Description

Motivation and Objectives

- Introduce factors that influence the outcomes of coexistence testing performed on wireless medical devices.
- Identify necessary testing steps that must be performed to implement a comprehensive test and obtain good representative results.
- Present several case studies that highlight appropriate and inappropriate coexistence testing practices.
- Describe a coexistence testing report (log)

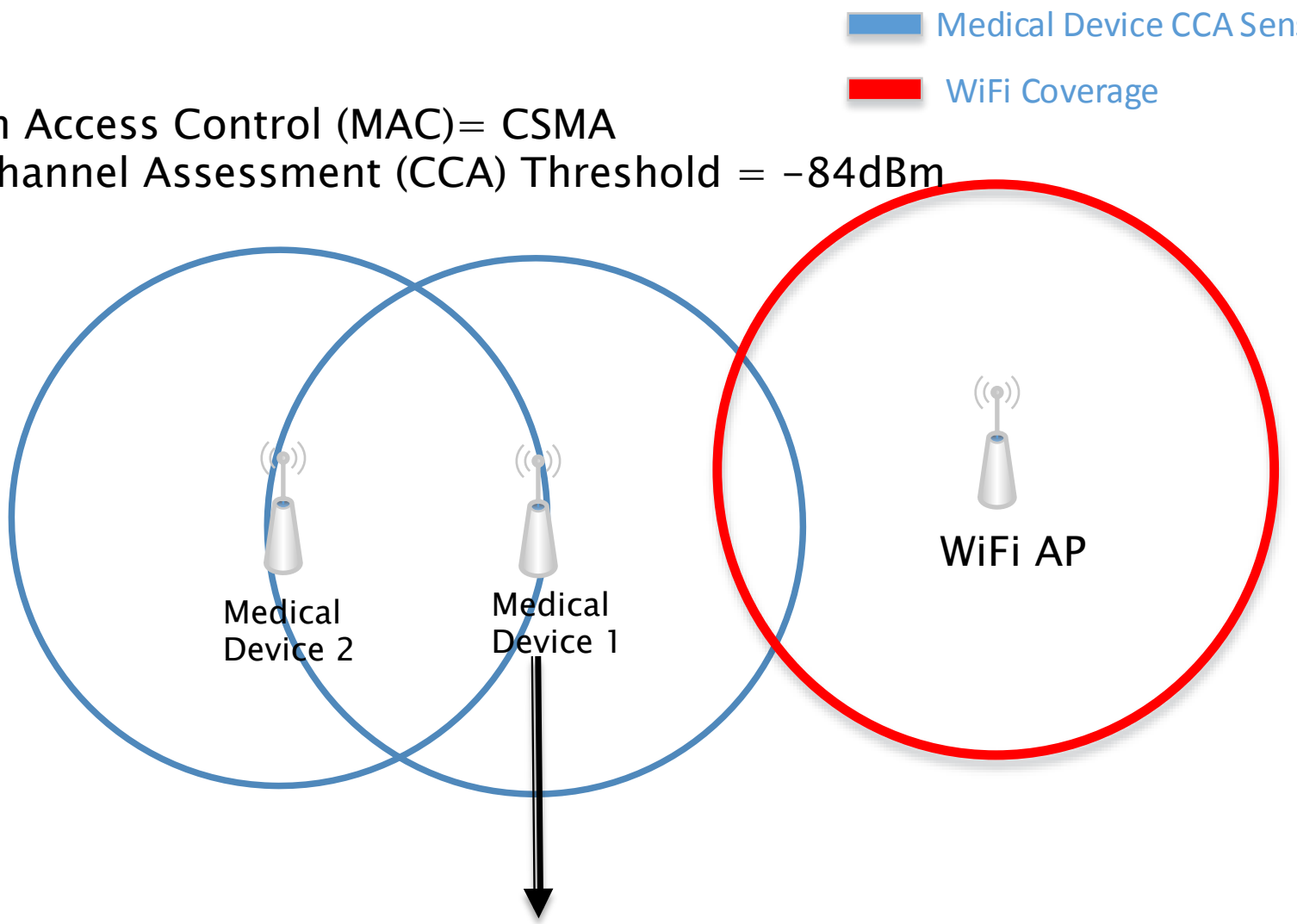
Coexistence Testing Parameters



Coexistence Factors (1): Power/Space

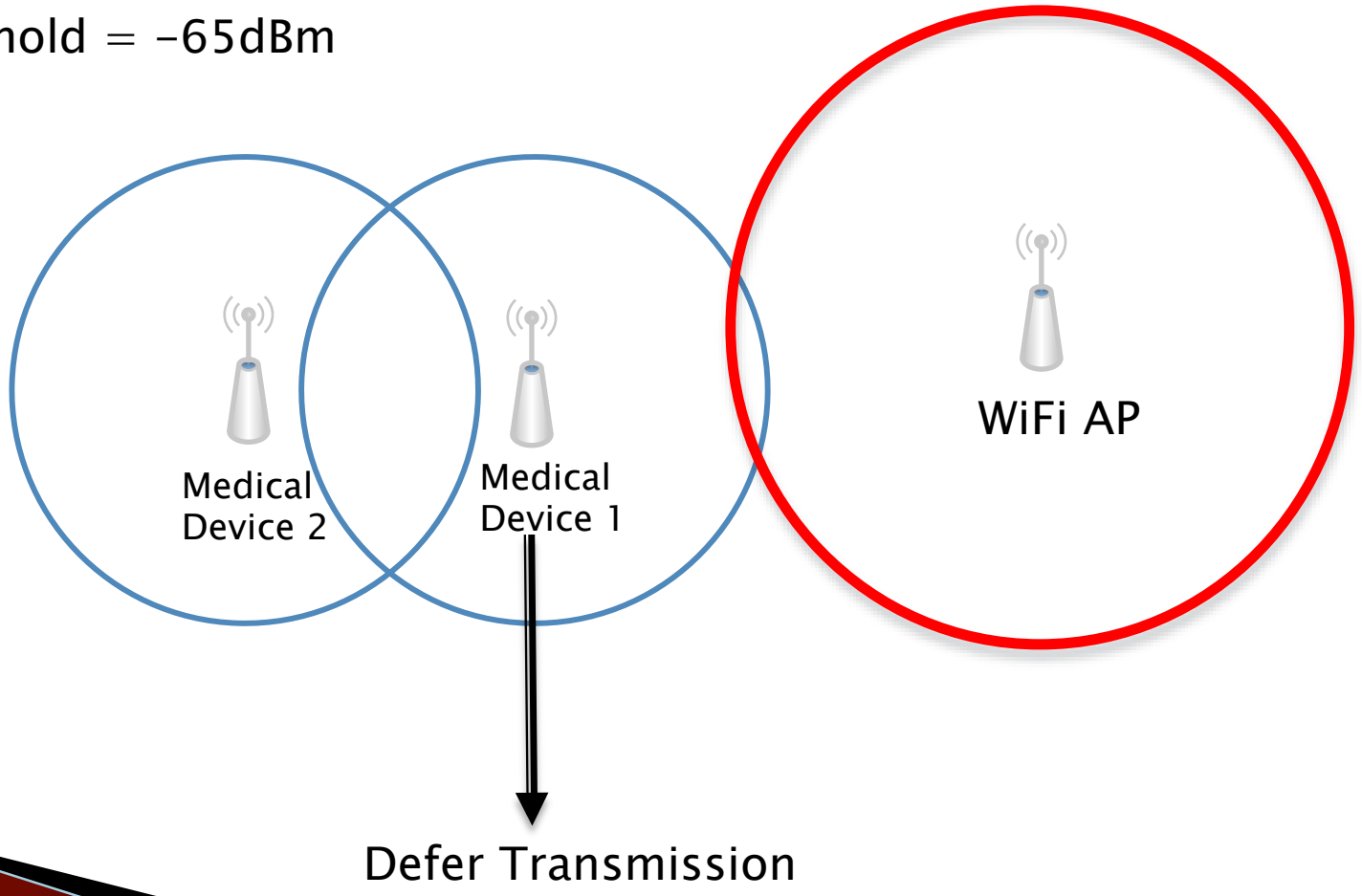
- Interference power at the medical device antenna is less than a given threshold. This translates to a sufficient Signal to Interference and Noise Ratio (SINR) at the receiver side of the communication link, enabling successful demodulation and information retention.
- At the transmitter side, it insures the device will not refrain from transmitting a packet because it senses that the wireless medium is occupied. Power can be portrayed alternatively by separation distance between a medical device and interfering devices in its vicinity, but we emphasis here only on parameters that can be directly sensed by the medical device.

Demonstration (Power/Space) :



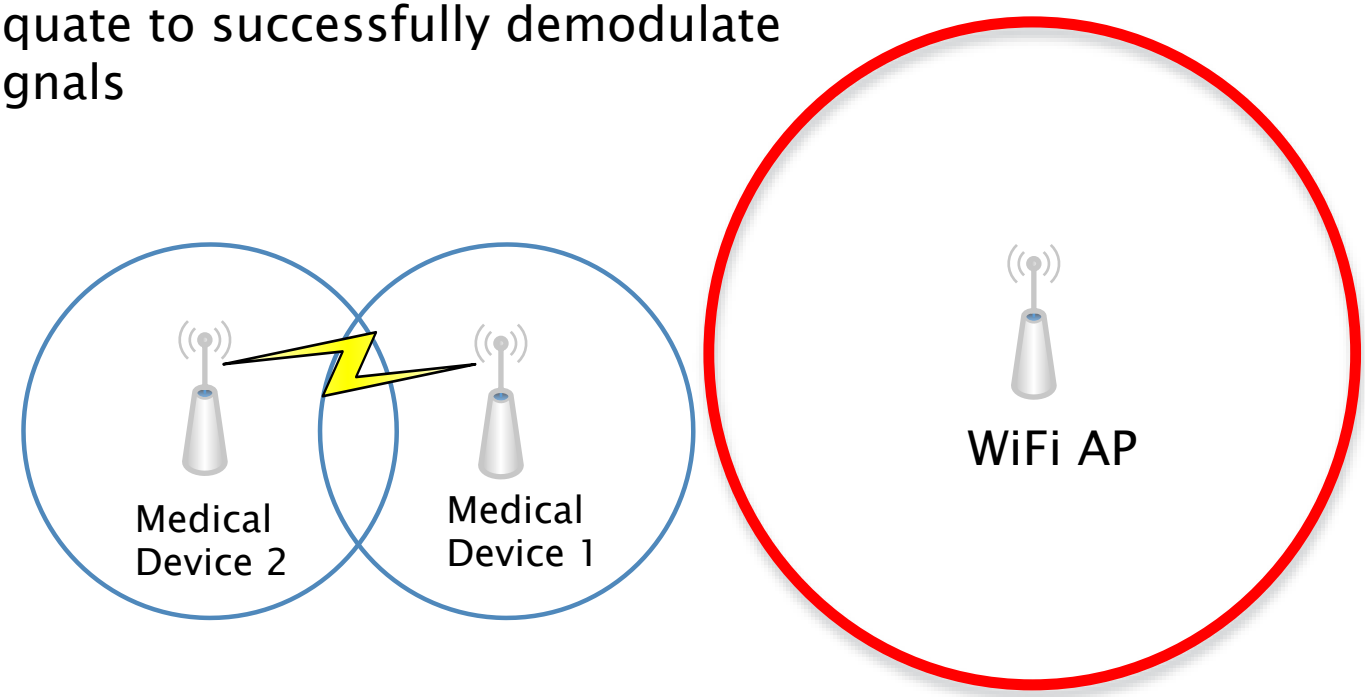
- Medium Access Control (MAC)= CSMA
- Clear Channel Assessment (CCA) Threshold = -84dBm

Demonstration (Power/Space) :



Demonstration (Power/Space) :

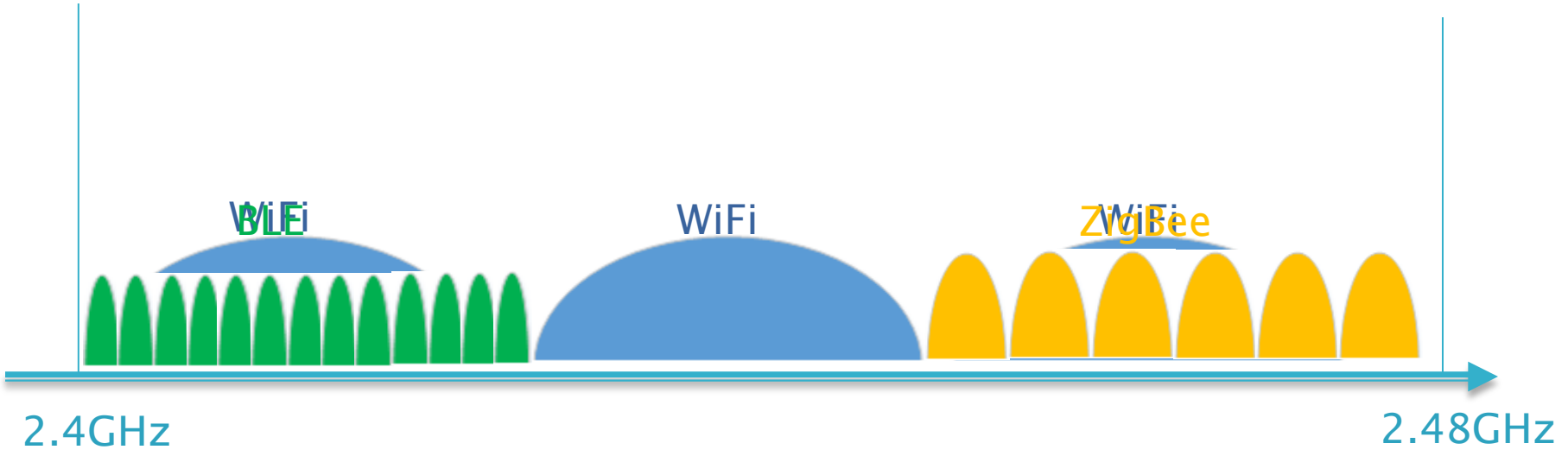
- CCA Threshold = -46dBm
- SINR is adequate to successfully demodulate intended signals



Coexistence Factors (2): Frequency

- Adequate separation between carrier frequency used by the medical device and frequencies occupied by interfering devices is required.
- Both co-channel interference and adjacent-channels have an effect on probability for successful communication.

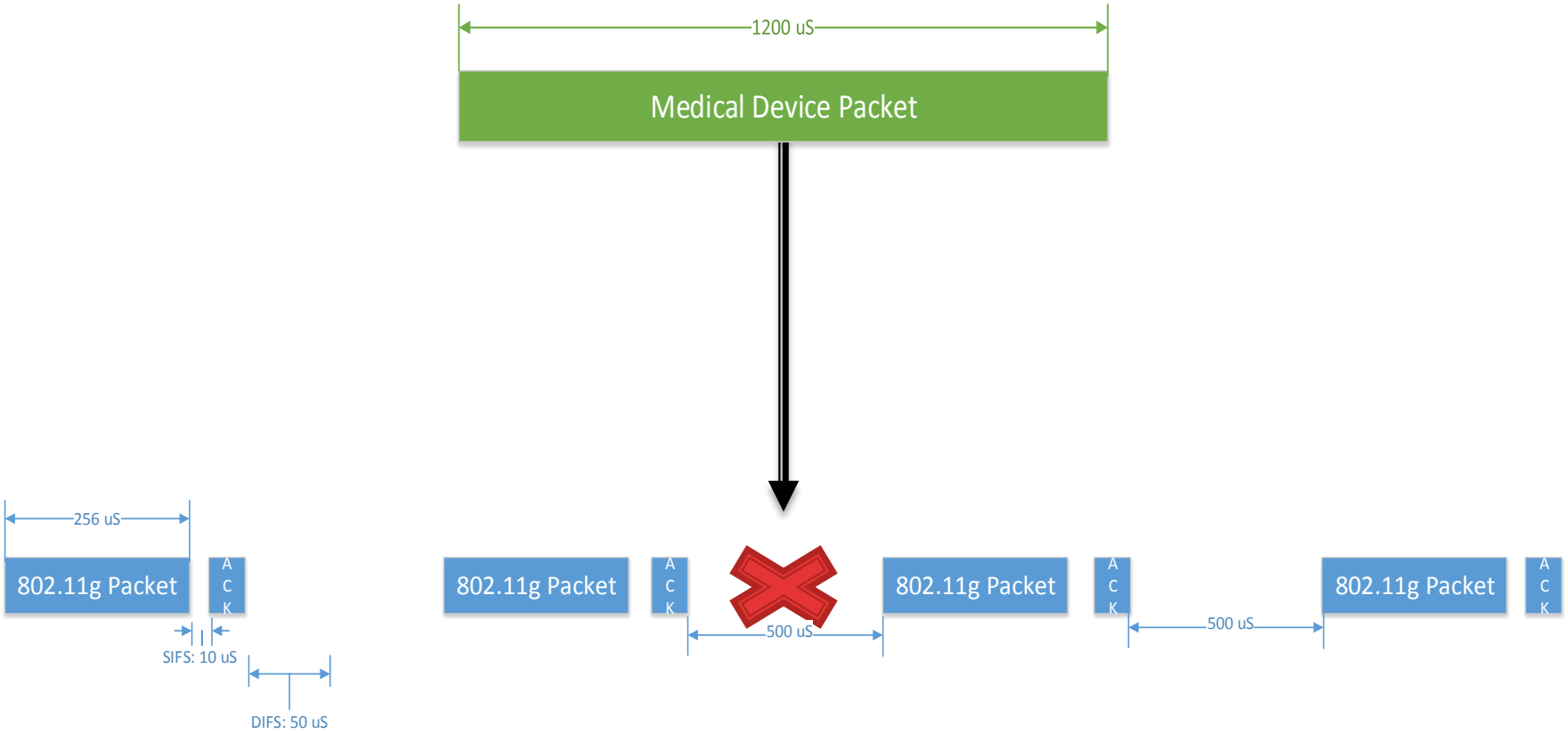
Demonstration (Frequency) :



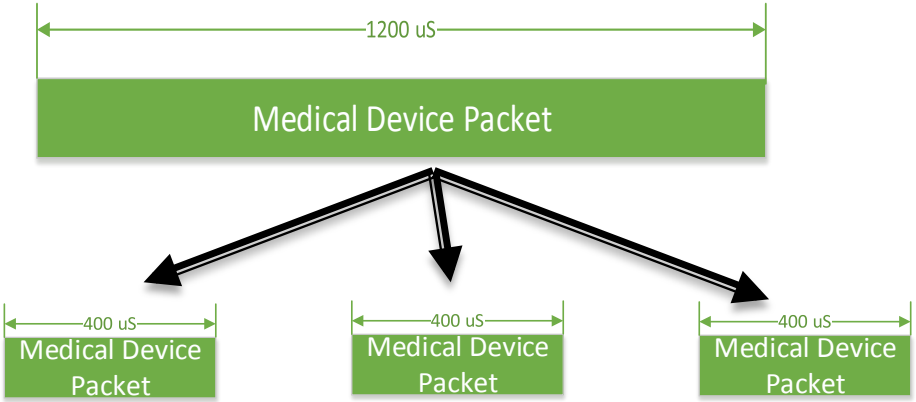
Coexistence Factors (3): Time

- A device attempting to transmit a packet of given length requires an available wireless medium (i.e., previous parameters of power and frequency are favorable for transmission) for a suitable period.
- Duty cycle has been identified as an indicator of spectrum temporal occupancy and an important figure providing insight into coexistence.
- Channel activity/inactivity probability density functions are essential to duplicate real-life channels

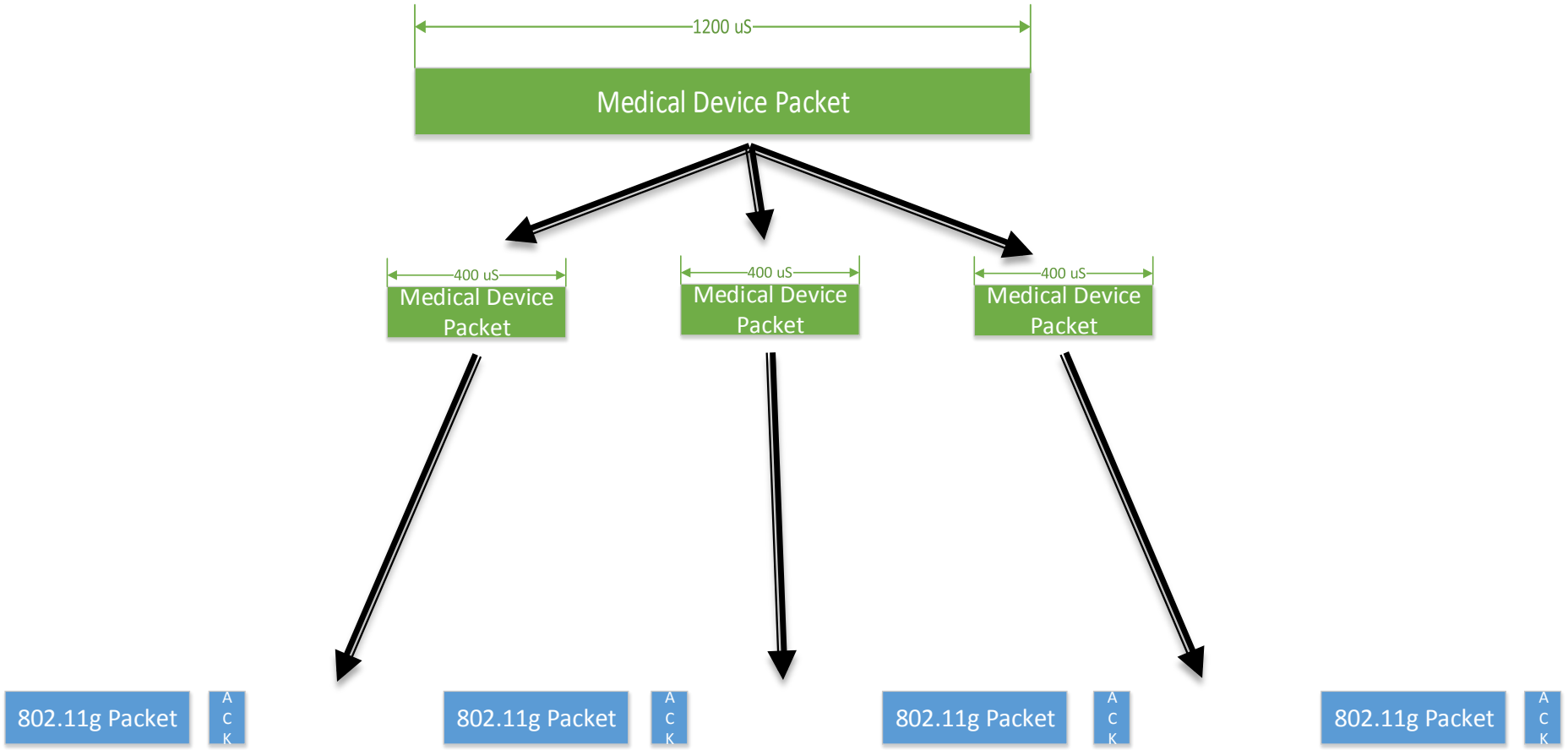
Demonstration (Time) :



Demonstration (Time) :



Demonstration (Time) :



Coexistence Testing Protocol (guideline)

- Characterize testing environment: distance, LoS, NLoS, & noise level.
- Choose an interfering network: wireless technology, single pair, dual pairs, etc.
- Characterize interfering network: power, time (duty cycle), and frequency (co-channel/adj-channel).
- Identify wireless medical device key performance indicator (KPI).
- Characterize wireless medical device under test in the testing environment without interfering network: power, time, CSMA, CCA, frequency, packet length.
- Introduce interfering network into the testing environment
- Monitor duty cycle and measure interfering power received at the medical device terminals.
- Collect KPI measurements.

Coexistence Test Reporting: Test Info

- The log consists of three sections:
  1. Test info.
  2. Interferer.
  3. Medical Device Under Test (DUT).
- Test Info: Contains indicative information about each test run, e.g. date, test number and test name (for example WiFi is the test name for all 802.11b/g/n setups).

Test Info		
Date	Test Name	Test Number
3/26/2015	Baseline	x
3/26/2015	WiFi	101
3/26/2015	WiFi	102

Coexistence Test Reporting: Interferer

- Interferer: Contains the following information regarding the interfering network parameters:
  - Technology: E.g. 802.11b/g/n, ZigBee, Bluetooth…etc.
  - Tx Power: Set transmit power level.
  - Throughput (before and after DUT starts): Reports measured throughput of the interfering network. A throughput value is set for the network to achieve. A normal observation is that the network is able to achieve the demanded throughput when DUT is OFF and a drop in throughput is witnessed when DUT is ON.

Interferer						
Network	Tx Power [dBm]	Throughput (Mbps) Before DUT starts	Throughput (Mbps) After DUT starts	Channel	Separation Distance (between Tx and Rx)	Duty Cycle
x		x		x	x	x
802.11b	8	7	0	2	2m	80.38
802.11b	8	7.8	7.8	6	2m	89.49

Coexistence Test Reporting: Interferer

- Channel: frequency at which interfering network is set to operate.
- Separation Distance: Measured separation distance between interfering network Tx and Rx nodes.
- Duty Cycle: temporal occupancy indicator measured by special equipment.

Interferer						
Network	Tx Power [dBm]	Throughput (Mbps) Before DUT starts	Throughput (Mbps) After DUT starts	Channel	Separation Distance (between Tx and Rx)	Duty Cycle
x		x		x	x	x
802.11b	8	7	0	2	2m	80.38
802.11b	8	7.8	7.8	6	2m	89.49

Coexistence Test Reporting: DUT

- DUT: Contains the following information regarding the device under test parameters:
  - Interferer Power @ Tx: Measured power caused by interfering network as the location of DUT Tx node.
  - Interferer Power @ Rx: Measured power caused by interfering network as the location of DUT Rx node.
  - Tx Power Setup: Some medical devices are designed to operate following EU or US regulations. This cell reports the power setup of the DUT.
  - Channel: frequency at which DUT is set to operate.
  - Separation Distance: Measured separation distance between DUT Tx and Rx nodes.

DUT														Follow-up
Interferer Power @ Tx	Interferer Power @ Rx	Tx Power Setup	Channel	Separation Distance (between Tx and Rx)	Observation: Interrogations (S/U)										Success Rate%	Interferer OFF
					1	2	3	4	5	6	7	8	9	10		
x	x	US	2420	1.5m	S	S	S	S	S	S	S	S	S	S		
-56.64	-48.25	US	2420	1.5m	S	S	U	S	S	S	S	S	S	S	90.00	Success

Coexistence Test Reporting: DUT

- Observations: Report the observations for the current test run. Usual parameters are: pass/fail, throughput, PER…etc.
- Success Rate%: In case observations were of pass/fail nature and the test is performed repeatedly, success rate is the ratio of pass instances to all performed test instances.
- Follow-up: Concludes a particular test-run. The interferer is turned OFF and the DUT is tested to make sure that it is operational and that prior observations were because of the interference phenomena.

DUT														Follow-up
Interferer Power @ Tx	Interferer Power @ Rx	Tx Power Setup	Channel	Separation Distance (between Tx and Rx)	Observation: Interrogations (S/U)										Success Rate%	Interferer OFF
					1	2	3	4	5	6	7	8	9	10		
x	x	US	2420	1.5m	S	S	S	S	S	S	S	S	S	S		
-56.64	-48.25	US	2420	1.5m	S	S	U	S	S	S	S	S	S	S	90.00	Success

Conclusion

- Coexistence parameters
- Frequency:
  - Co-channel/Adj-channel
- Time
  - Channel duty cycle, and
  - Temporal distributions
- Power/Space
  - Interfering transmission power,
  - Interfering received power at MD (Tx, Rx),
  - Separating distances, and
  - CCA threshold if CSMA used.