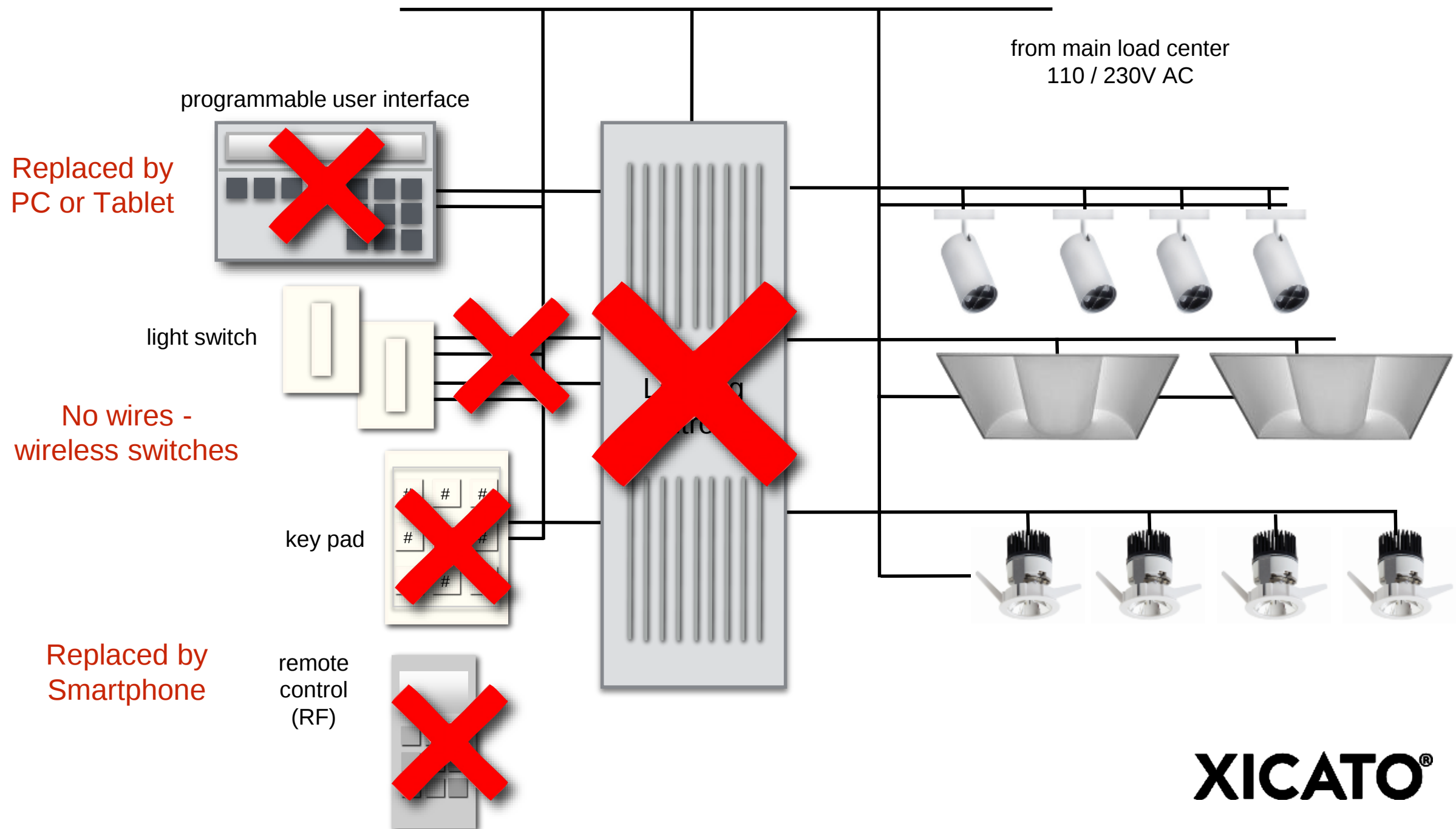




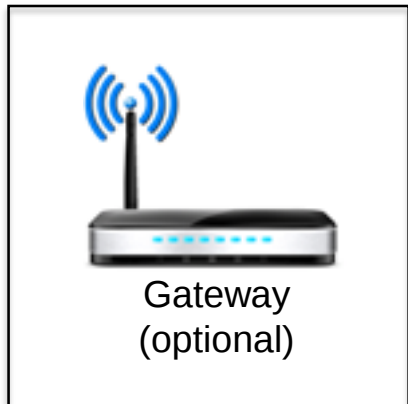
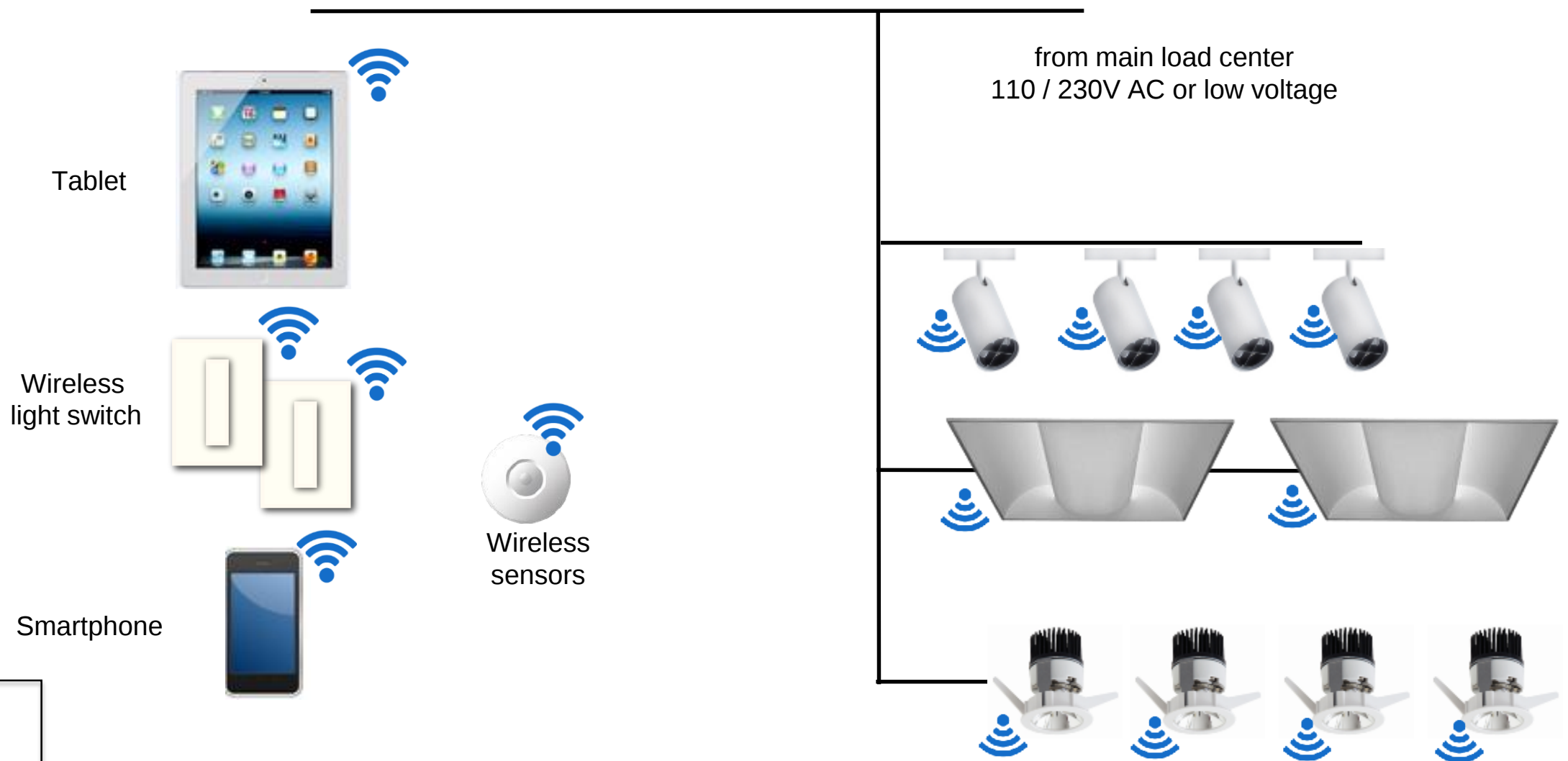
XICATO® GalaXi™

Bluetooth

Centralized lighting control is too expensive, complex and inflexible



Bluetooth lighting control system



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network lesson in 2 slides

The Open Systems Interconnect (OSI) stack

Layer	Name	Unit	Responsibility	Examples
7	Application		High-level APIs, including resource sharing, remote file access.	Bluetooth Mesh
6	Presentation	Data	Translation of data between a networking service and an application, including character encoding, data compression and encryption.	Bluetooth Mesh
5	Session		Managing communications sessions, i.e. back-and-forth messaging between applications.	Bluetooth Mesh
4	Transport	Segment (TCP) or Datagram (UDP)	Reliable or best-effort transmission of data between nodes, including segmentation and multiplexing of data, and acknowledgement of packet receipt (or not).	TCP, UDP, Zigbee, Bluetooth Mesh
3	Network	Packet	Structuring and addressing a multi-node network, including addressing, routing, and traffic control.	IP, Zigbee, Bluetooth Mesh
2	Medium Access Control (MAC)	Frame	Reliable transmission of data frames between two nodes connected by a physical layer. May include frame prioritization, segmentation and error checking.	Ethernet, 802.15.4, Wifi, Bluetooth
1	Physical Layer (PHY)	Bit	Encoding of raw bit streams for transmission and reception over a physical medium (radio, fiber optic, copper, coax).	8B/10B, 802.15.1 (Bluetooth), GFSK, FHSS, OFDM, QAM, TDM, CDMA, etc.

topologies

point-to-point

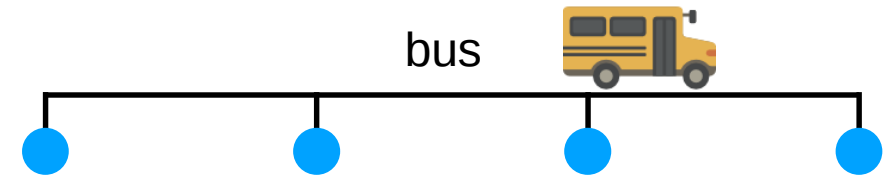


"link"

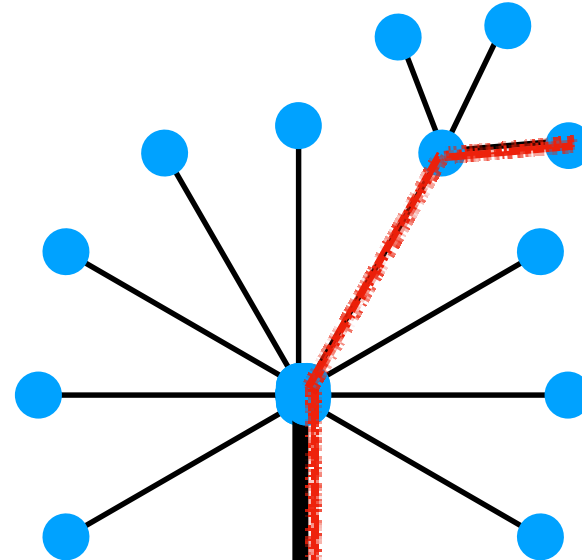
linear



bus



hierarchical tree

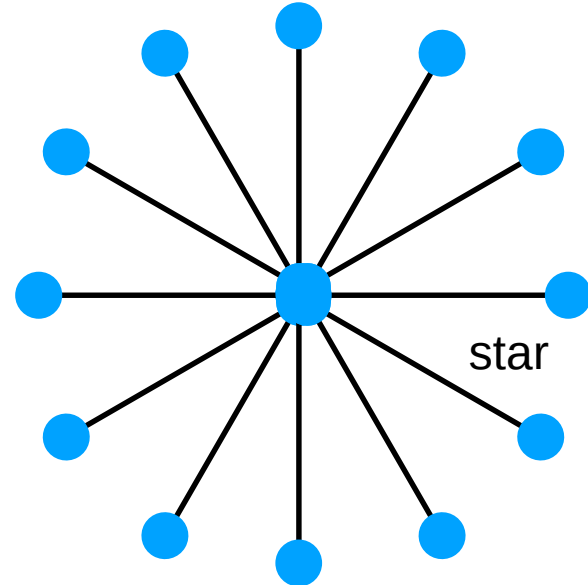


tree and branch

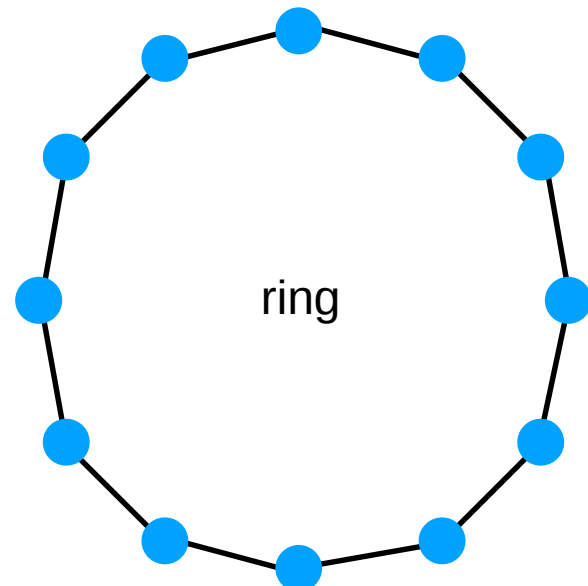
trunk

"path"

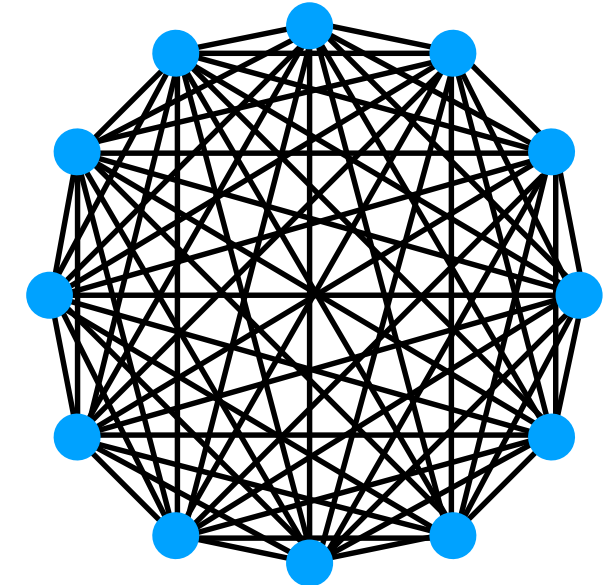
branch



star



ring



full mesh

$n(n-1)/2 = 66$ links for 12 nodes

499,500 links for 1000 nodes

(ouch!)

**BROADCAST CREATES ~FULL MESH
WITHOUT THE COMPLEXITY**

+ HYBRID

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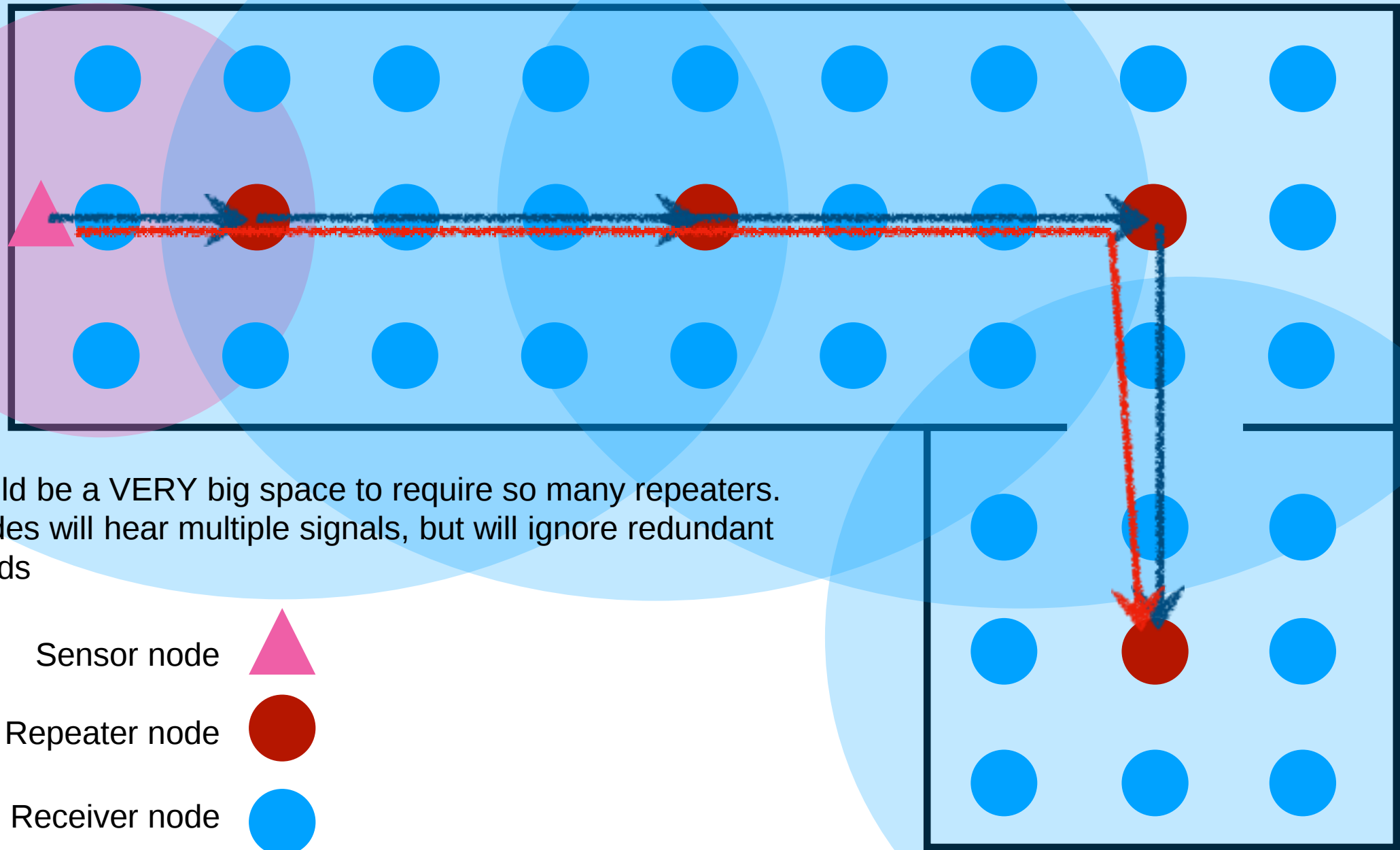
flood mesh

Sensor signal can be weaker

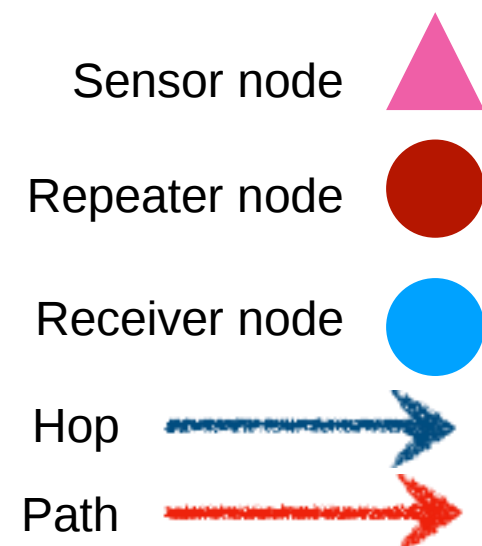
Signal propagation attenuated by walls

Repeaters can be any active Bluetooth node - XIM, XID, wired sensors, or dedicated nodes

Repeaters have no forwarding table to maintain- don't need to know who is listening



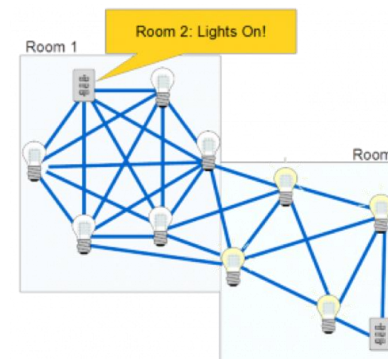
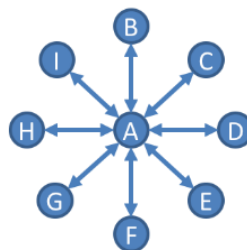
This would be a VERY big space to require so many repeaters.
Most nodes will hear multiple signals, but will ignore redundant commands



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Bluetooth evolution

Bluetooth Classic	Bluetooth Low Energy	Bluetooth Mesh	Bluetooth 5
Dedicated 1 to 1 pairing for point-to-point (one-to-one) connections	No dedicated pairing; one-to-many or many-to-many through broadcast/advertisement/publish-and-subscribe model.	Adds network layer protocol (mesh, security, etc.) AND new standard use (Application) models to BLE 4.x	Optional higher speed (1.7x) physical link layer with optional forward error correction (FEC). Applies to Classic, BLE and Mesh
Enables short range comms for mice, keyboards, etc. EDR (extended data rate) maximizes bandwidth for audio.	Enables beacons and device group control (lights, etc.).	Extends network range, minimizing need for gateways. Enables application level interoperability for IoT	Improves scalability and performance in dense networks, and extended range (at lower speed) in sparse networks.



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wireless cooperation

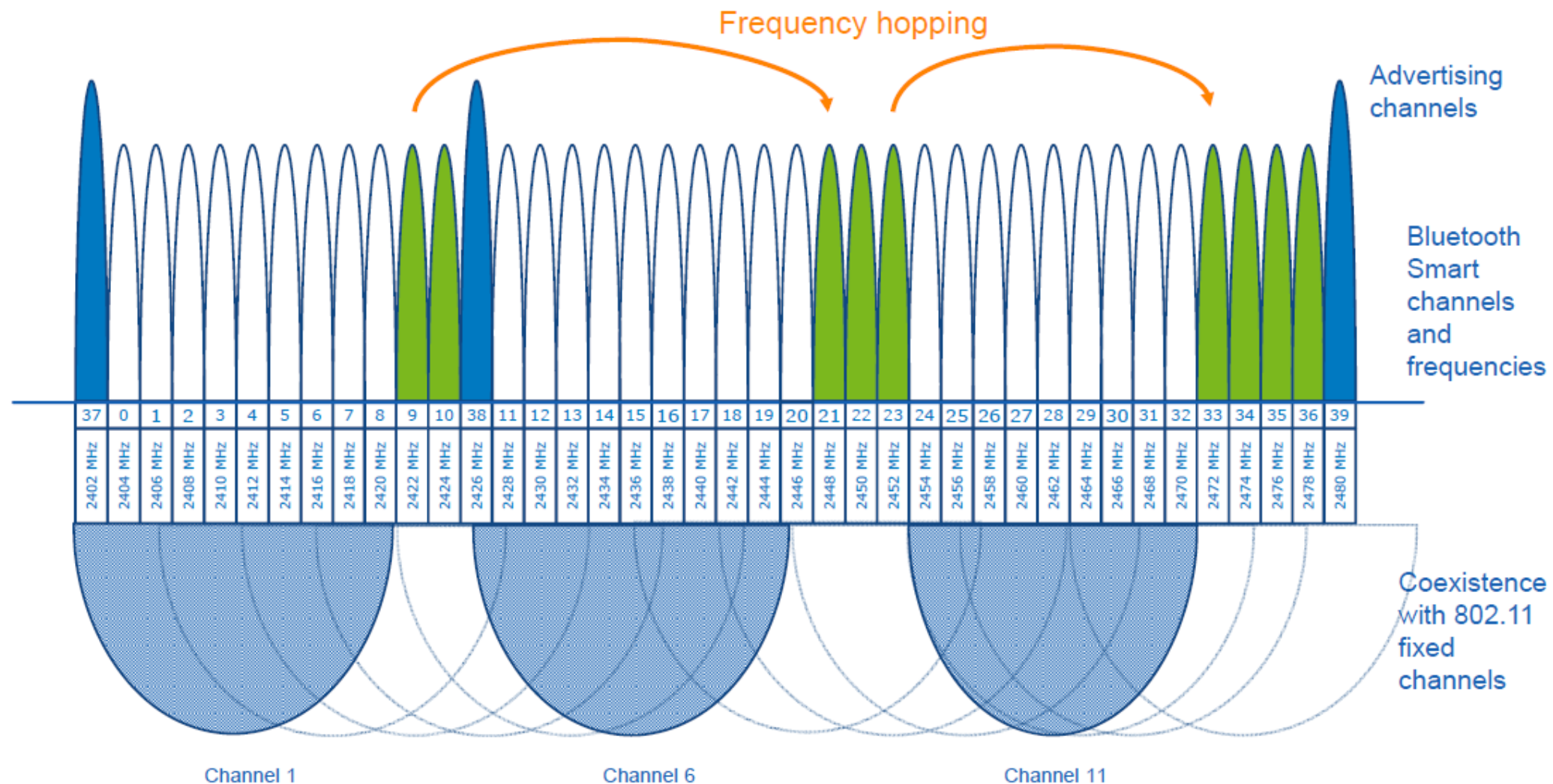
BLE talks softly

DBM	DBW	WATTS	TERMINOLOGY
+100	+70	10 000 000	10 Megawatts
+90	+60	1 000 000	1 Megawatt
+80	+50	100 000	100 kilowatts
+70	+40	10 000	10 kilowatts
+60	+30	1 000	1 kilowatt
+50	+20	100	100 watts
+40	+10	10	10 watts
+30	0	1	1 watt
+20	-10	0.1	100 milliwatts
+10	-20	0.01	10 milliwatts
0	-30	0.001	1 milliwatt
-10	-40	0.0001	100 microwatts
-20	-50	0.00001	10 microwatts
-30	-60	0.000001	1 microwatt
-40	-70	0.0000001	100 nanowatts
-50	-80	0.00000001	10 nanowatts
-60	-90	0.000000001	1 nanowatt

Wifi can broadcast at much higher power, so Bluetooth will not disrupt Wifi.
But will Wifi disrupt Bluetooth?...

BLE dances around Wifi

A properly configured WiFi network shouldn't interfere with the Bluetooth signal. The best practice for WiFi configuration is enabling WiFi on one of the following channels: 1, 6, 7, 8, 9, 10, 11, 12. Other channels: 2, 3, 4, 13, 14 might cause interference with Bluetooth signal and it's best to avoid them. When configuring three different WiFi networks the best solution is to use channels 1, 6 and 11. This prevents Wifi channels from interfering with each other and with BLE channels.

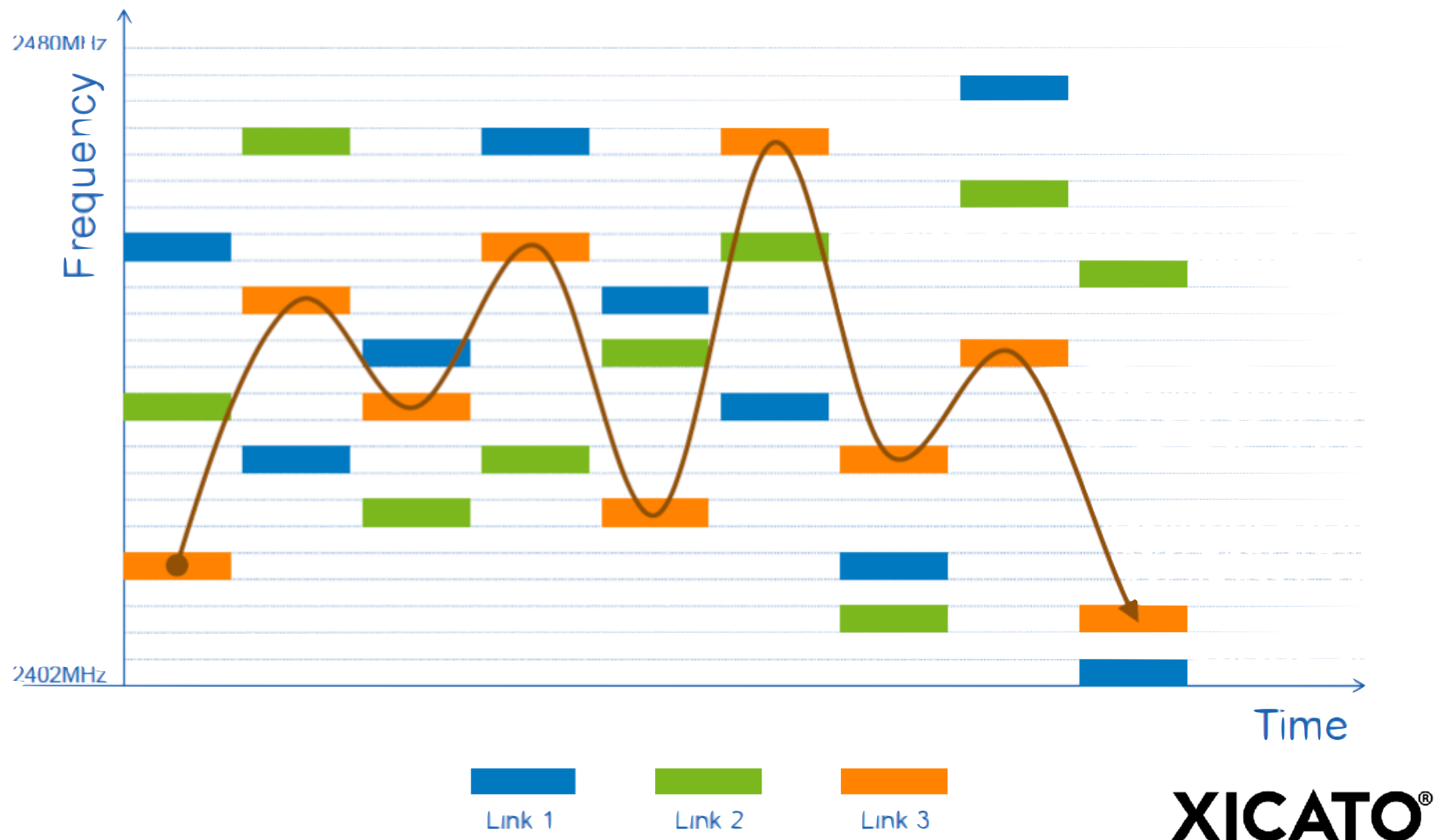


- Blue channels for “public” communications (broadcasts)
- Green (and white when available) for private, connection-oriented communications (OTA updates, detailed status, provisioning and configuration).

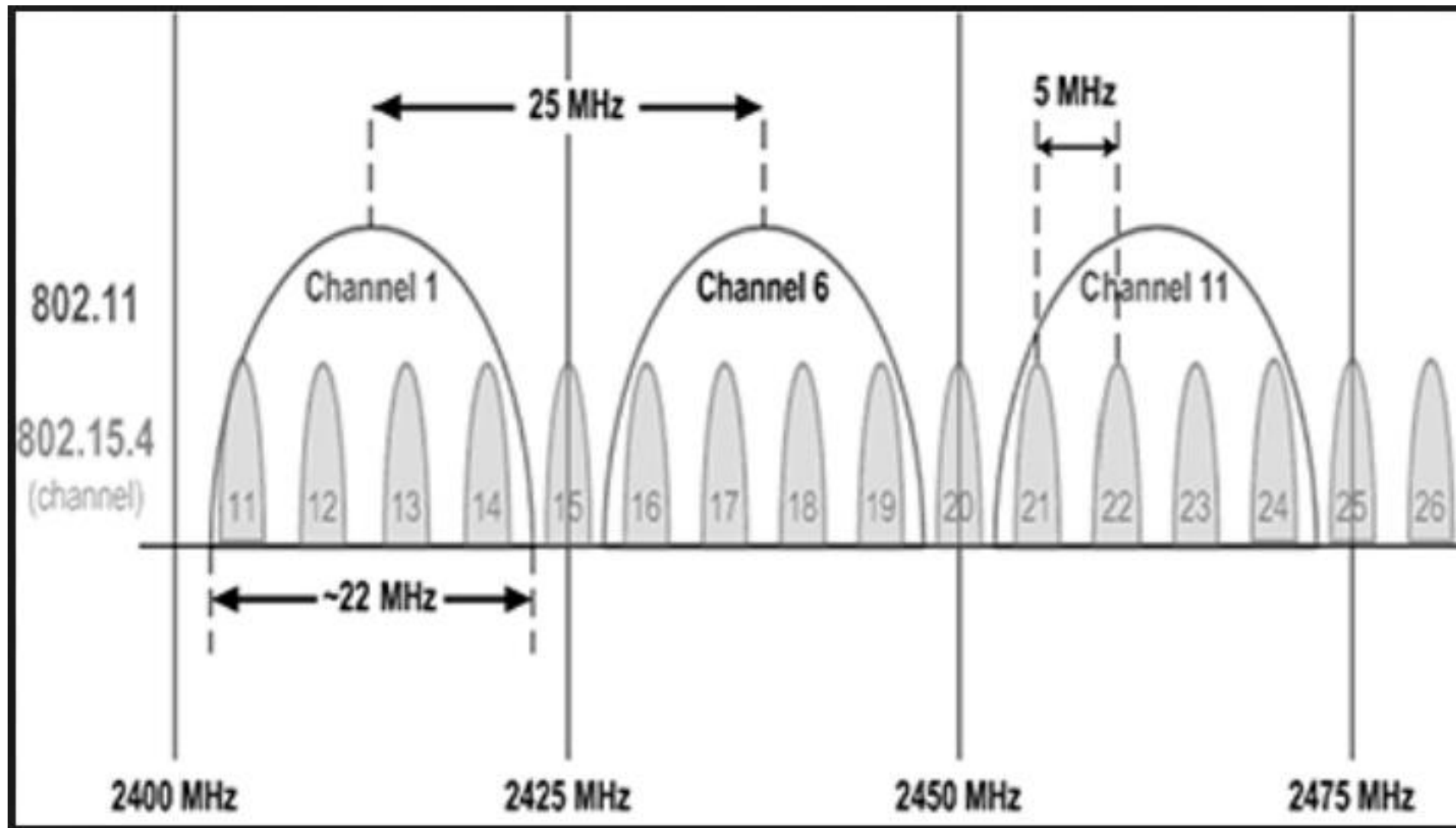
BLE employs frequency hopping spread spectrum

Bluetooth uses frequency hopping spread spectrum (FHSS) technology **on connection-oriented communications**, in which the signal changes channels in a predetermined pattern at a rate of 1600 hops per second (625µs between hops). This technique was designed to reduce interference between wireless technologies sharing the 2.4 GHz spectrum.

Broadcasts in Mesh accomplish a similar purpose by transmitting each message multiple times on multiple channels.



802.15.4 (Zigbee) competes with Wifi in 2.4 GHz



NOT appropriate for mobile devices

Require a “coordinator node” per network of up to 127 devices.

“With low transmit power, the widely deployed IEEE 802.15.4-based networks are easily interfered with by other 2.4GHz wireless networks, such as IEEE 802.11.”

<http://journals.sagepub.com/doi/full/10.1155/2011/912152>

Direct Sequence Spread Spectrum (DSSS) is one technology applied to minimize this.

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About Bluetooth 5

“Bluetooth 5 gives you twice the bandwidth
and 4 times the range.”

– *Bluetooth 5 misconception*

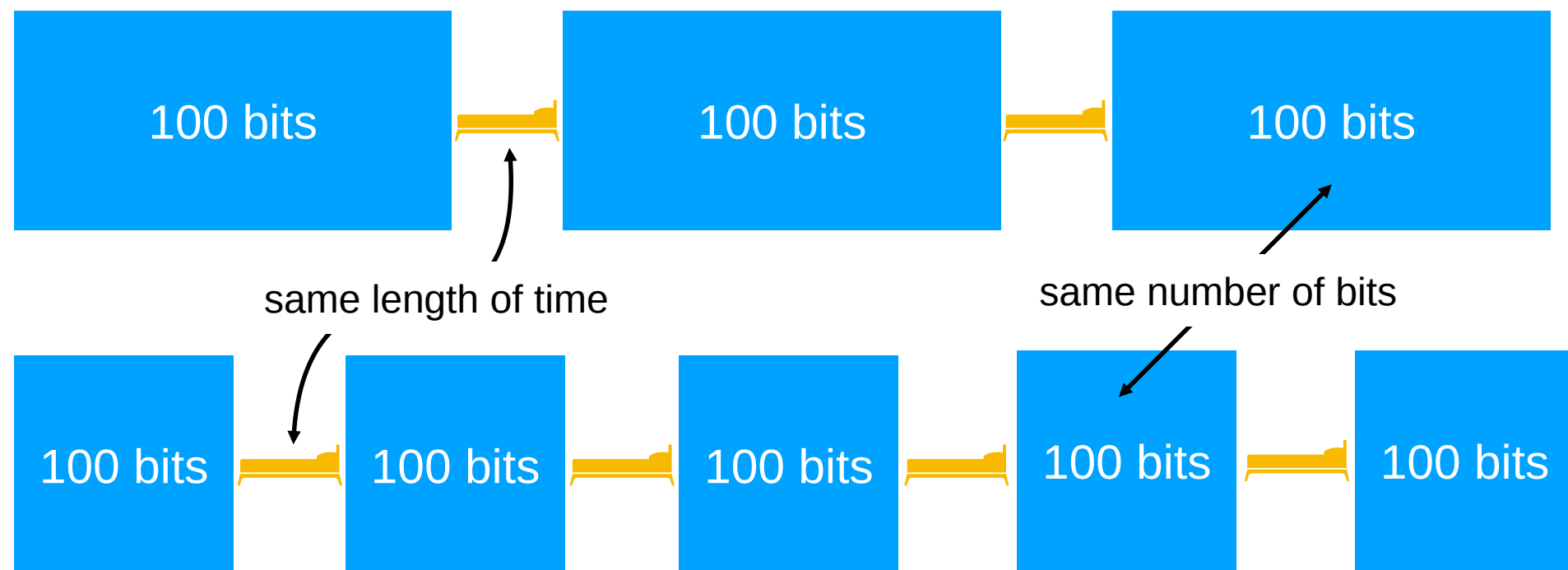
comparing the protocols - how fast?

	BLE 4.2	BLE 5	BLE 5 Long Range (S=2)	BLE 5 (S=8)
Connection Speed	1 Mbps	2 Mbps	1 Mbps	1 Mbps
Network data rate	1 Mbps	2 Mbps	500 kbps	125 kbps
Data throughput	800 kbps	1400 kbps	380 kbps	109 kbps
Forward Error Correction	None	None	FEC	FEC
Bluetooth 5 requirement	Mandatory	Optional	Optional	Optional

Bluetooth 5 allows you to increase bandwidth OR range, but not both at the same time.

Bluetooth 5 makes BLE 4.2 mandatory, but bandwidth and range extension are optional

mind the gap



Bluetooth 5 transmission speed (bit rate) is 2x as fast, but the inter-frame space (time between packet transmissions) is the same. The gap therefore eats twice as many of those faster bits; so the actual data rate improvement is not 2x but rather 1.7x

techie tidbits

- The traditional way to increase Range is by increasing transmission power, but this consumes more energy, and there is a maximum power allowed by legal standards...
- To get around this, you can either reduce the data rate, or use Forward Error Correction (FEC). FEC multiplies the number of bits required to send a given message, but this consumes useful bits, reducing effective bandwidth (throughput). So increasing range with FEC reduces data throughput at a given power level.
- The further away you go, the smaller the difference between standard Bluetooth 5 (not the long-range, coded version) and Bluetooth 4.2. At the edge of the standard range, Bluetooth 5 can actually deliver lower throughput, because small errors in time have a bigger impact on throughput.

what does this mean?

- Bluetooth 5 is 1.7x as fast as BLE 4.2 at short range
- You don't get speed AND range... in fact, you get much less speed when you increase range...
- But at least you can choose one or the other

“Bluetooth 5 *can* give you 1.7 times the throughput
OR
4x the range at a fraction of the throughput.”

– *Bluetooth 5 reality*

Autonome verlichtingsregeling en/of geconnecteerd, tweerichtingsverkeer

