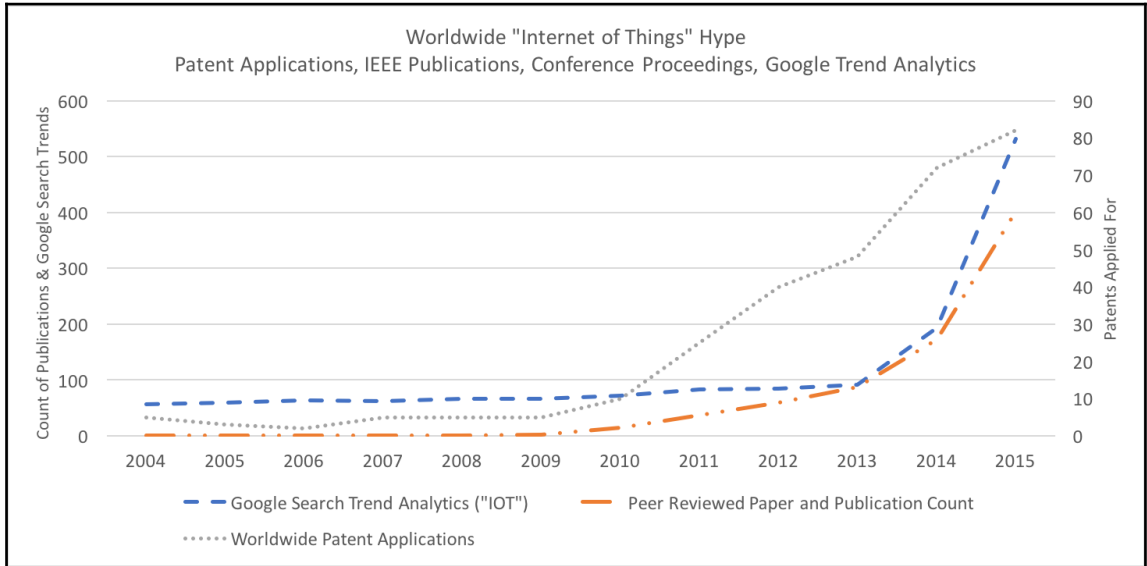
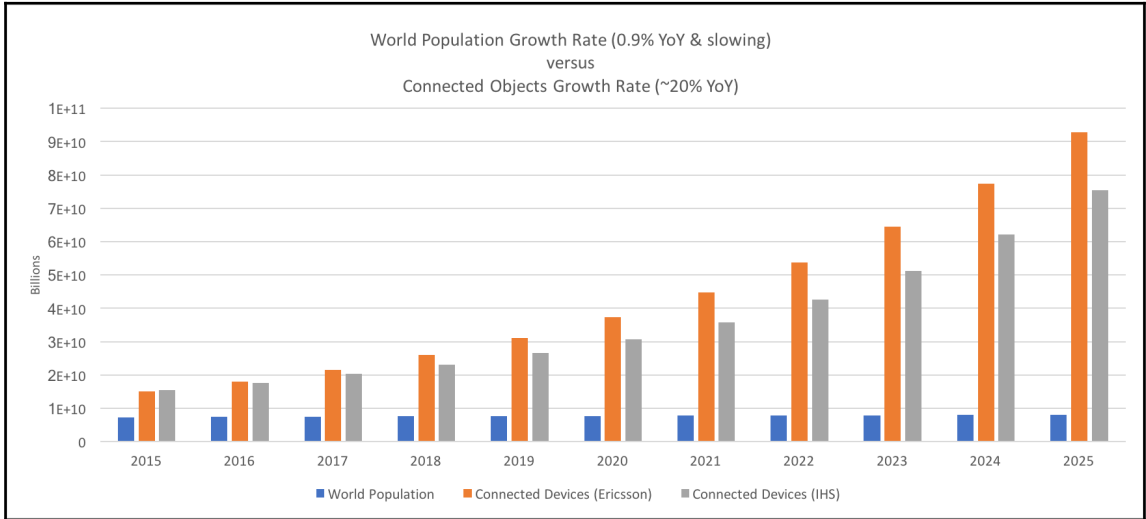
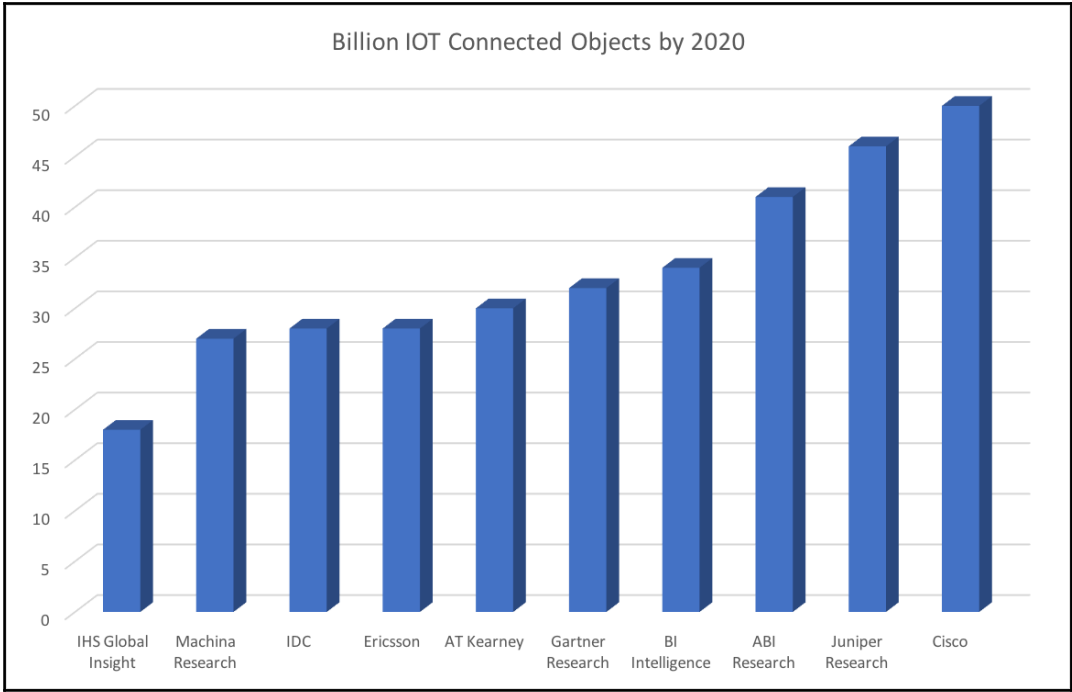


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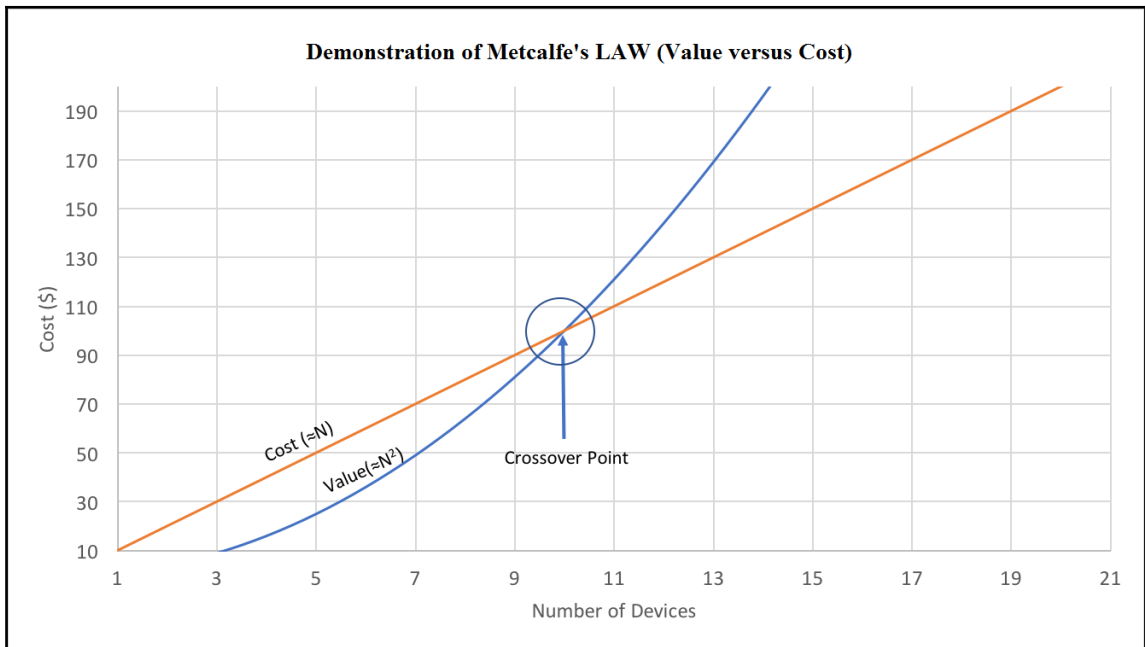
Chapter 1: The IoT Story



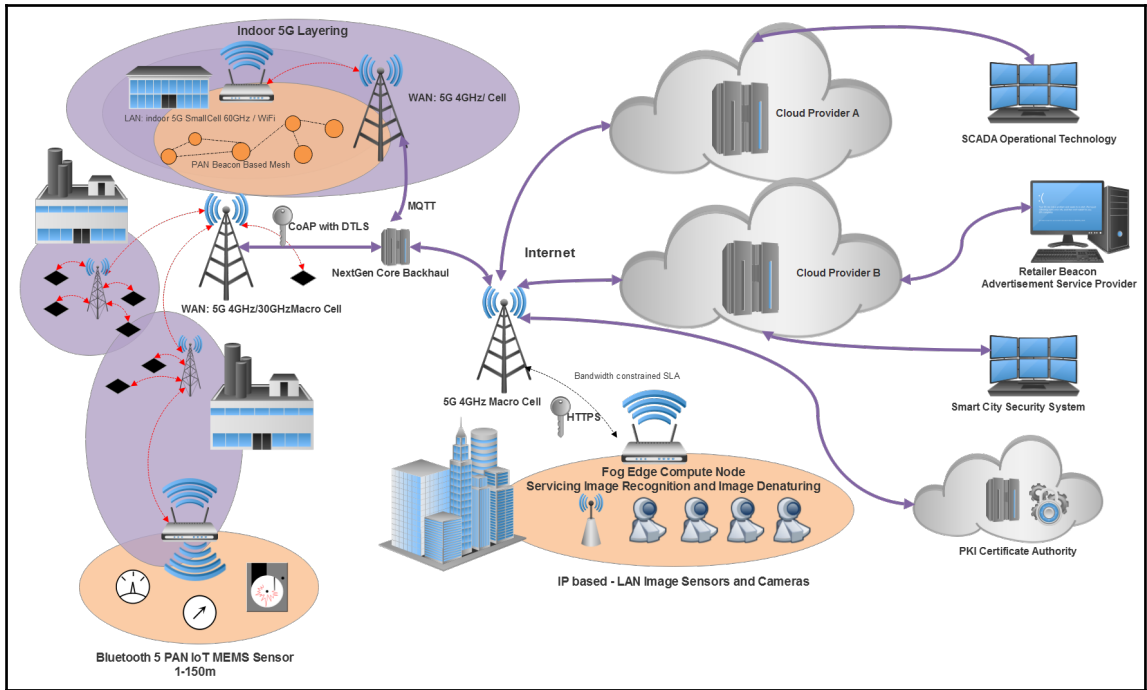


Chapter 2: IoT Architecture and Core IoT Modules

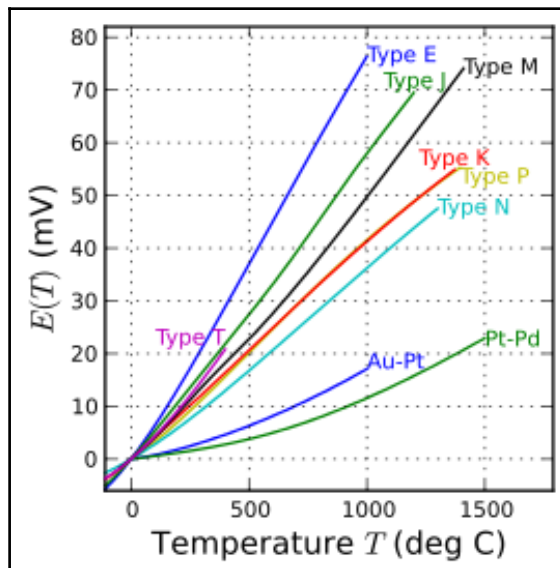
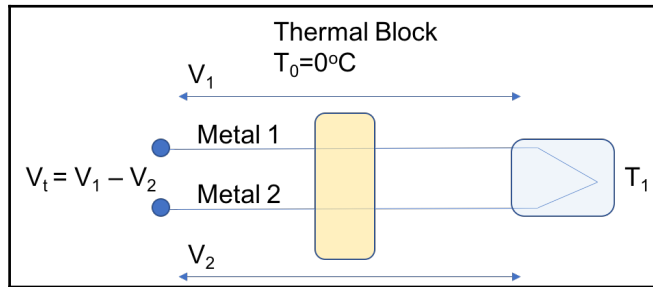
$$V \propto N^2$$

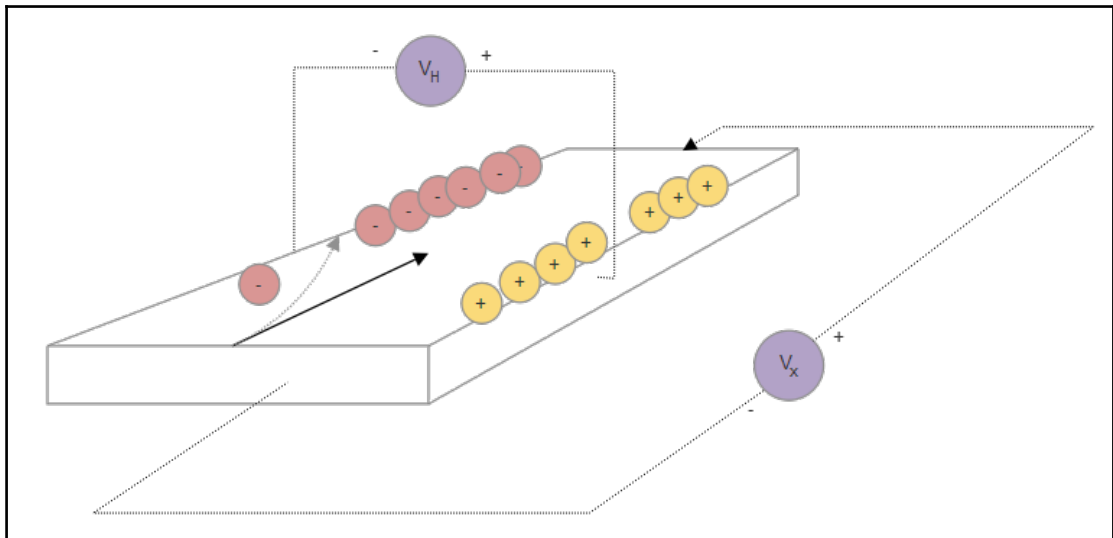
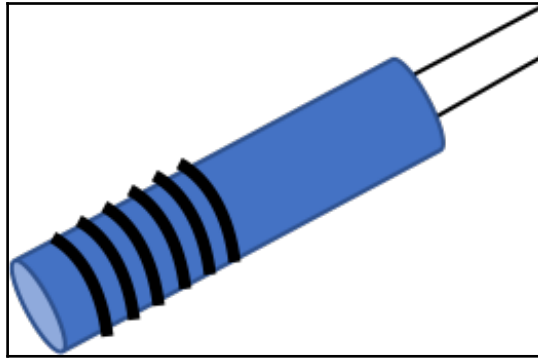


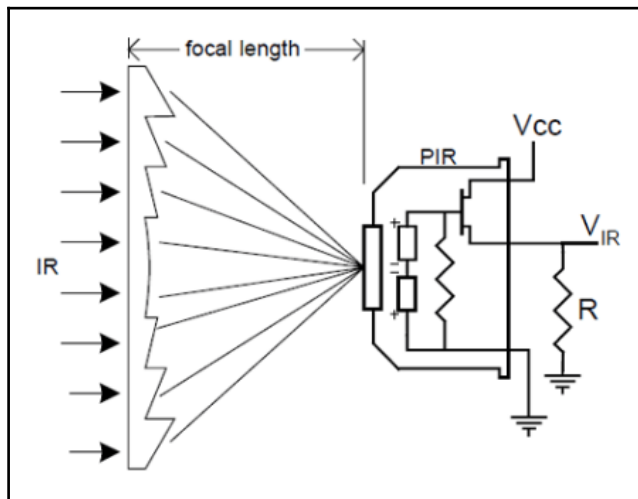
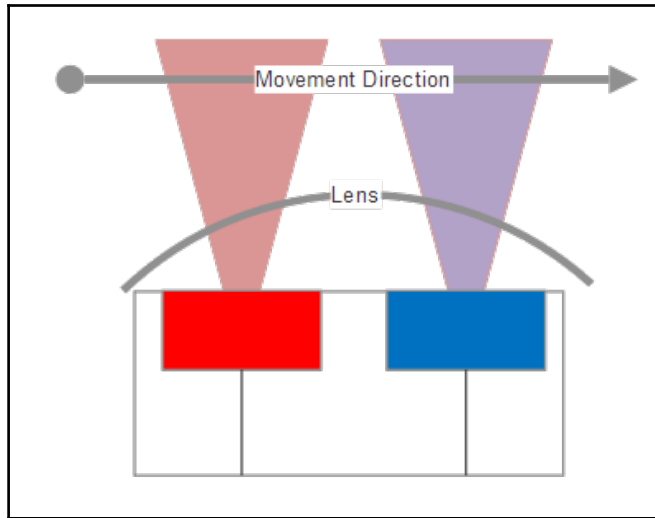
$$\sum_{i=1}^n V_{i,j} = \sum_{i=1}^n \sum_{k=1}^m \frac{B_{i,j,k} - C_{i,j,k}}{(1 + r_k)^{t_k}}$$



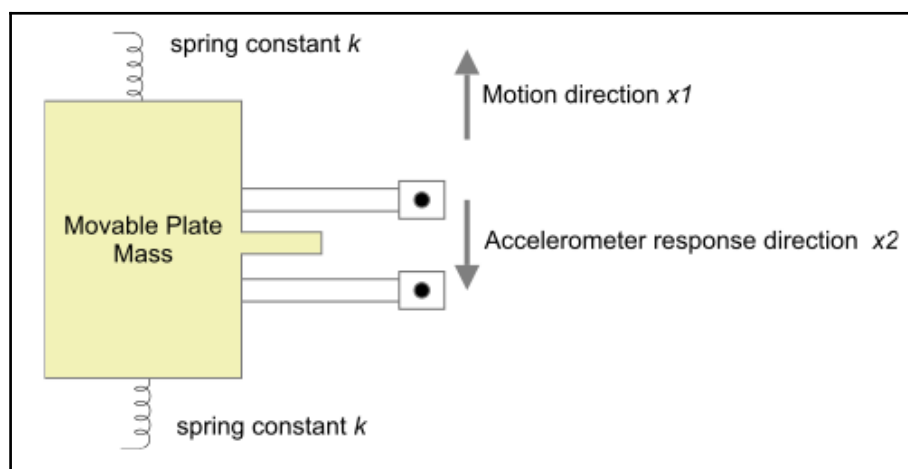
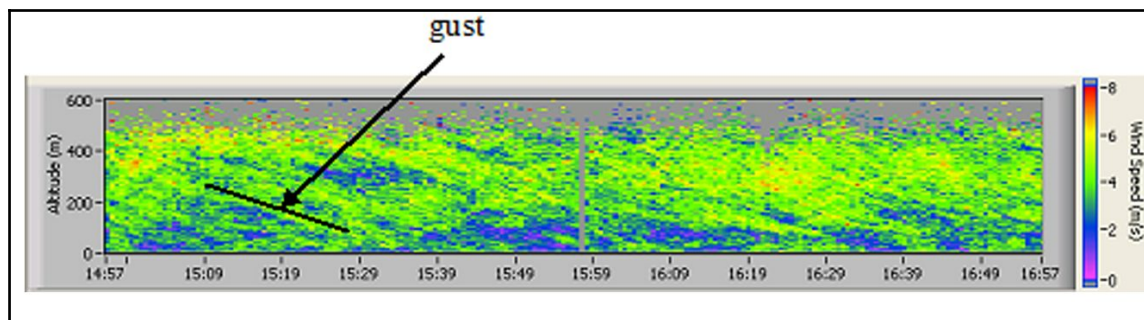
Chapter 3: Sensors, Endpoints, and Power Systems

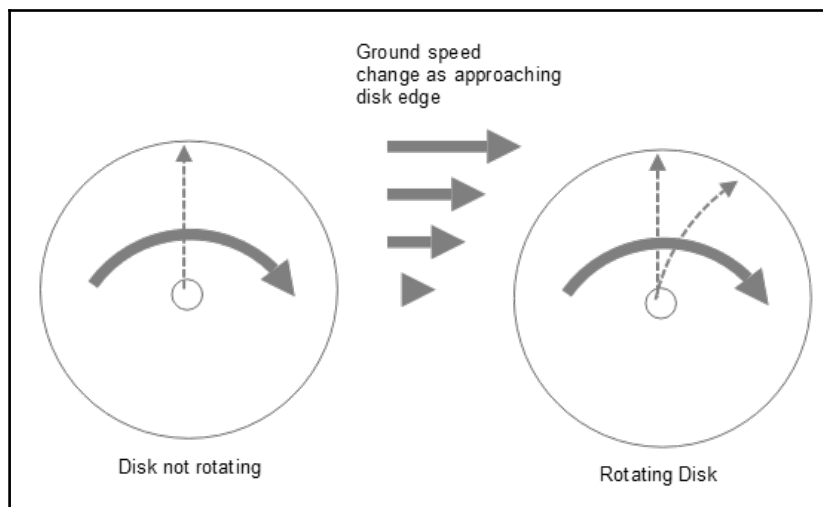




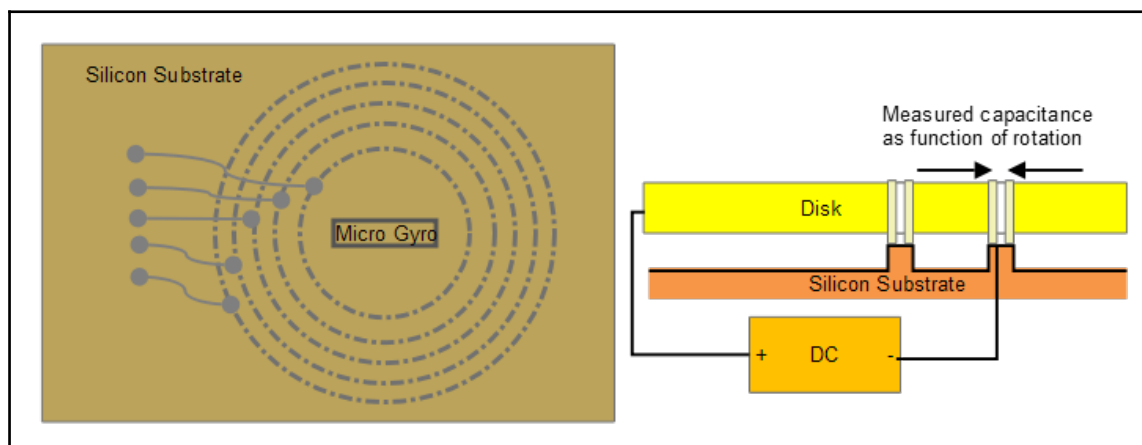


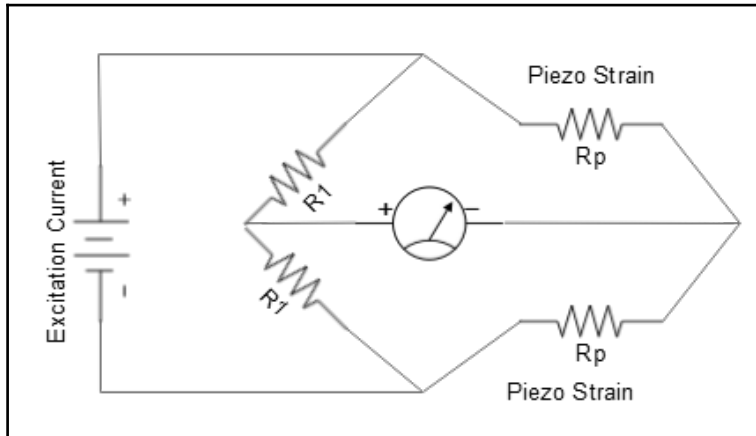
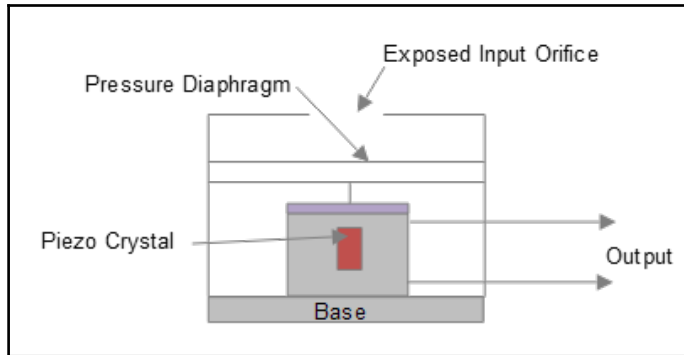
$$Distance = \frac{(Speed\ of\ Light \times Time\ of\ Flight)}{2}$$

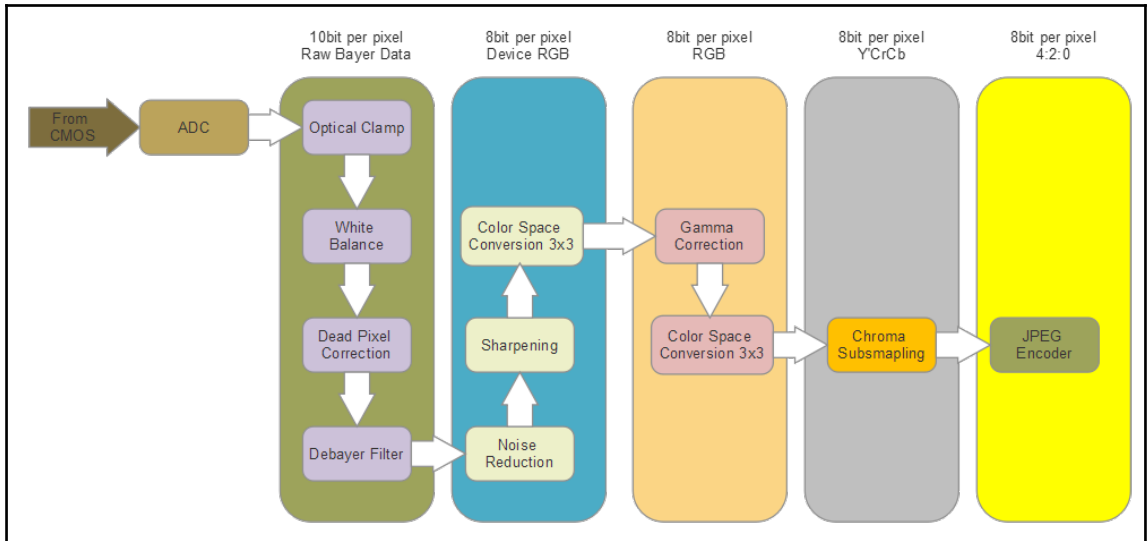




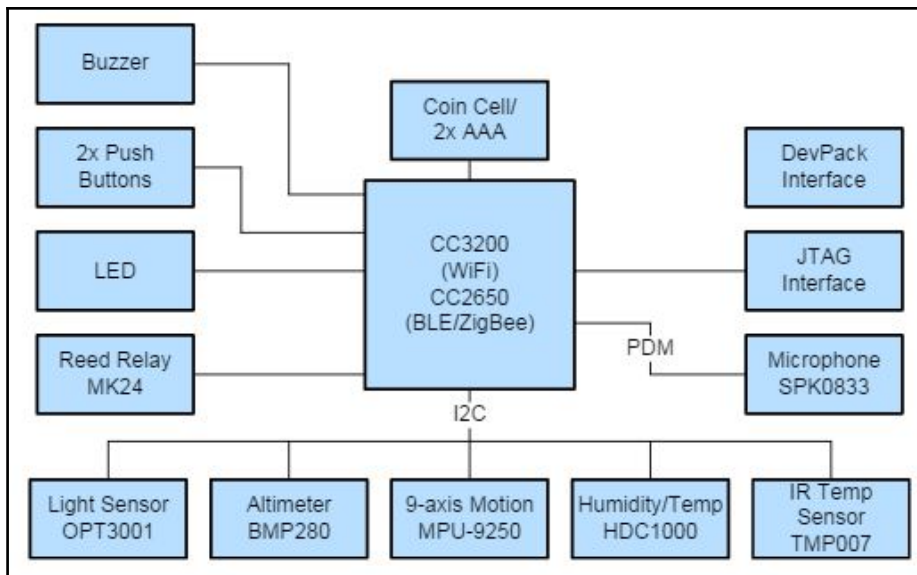
$$a = -2\omega \times v$$

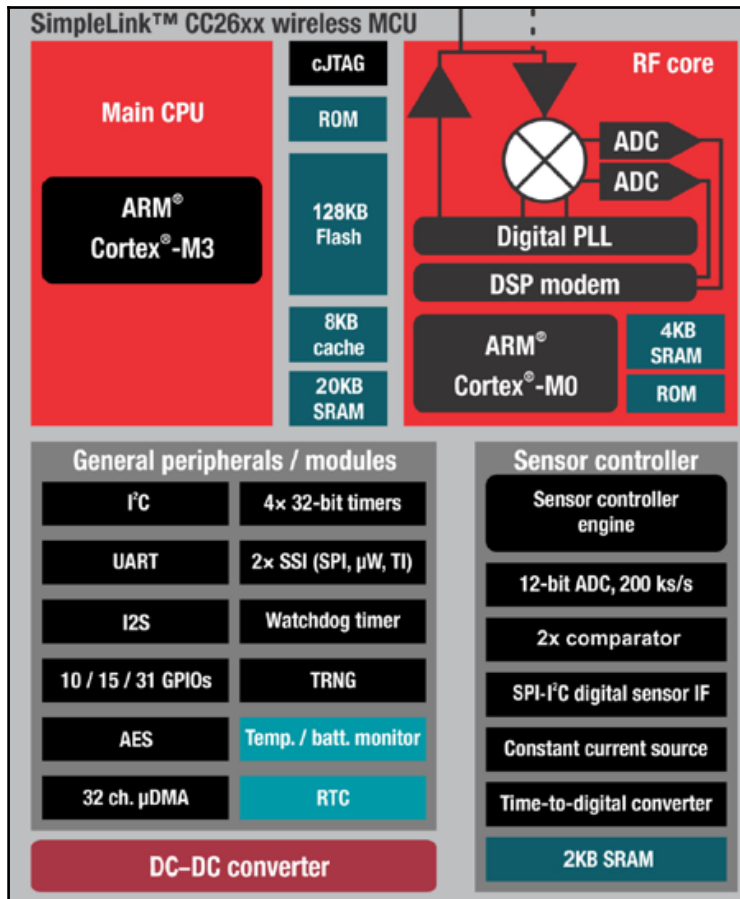


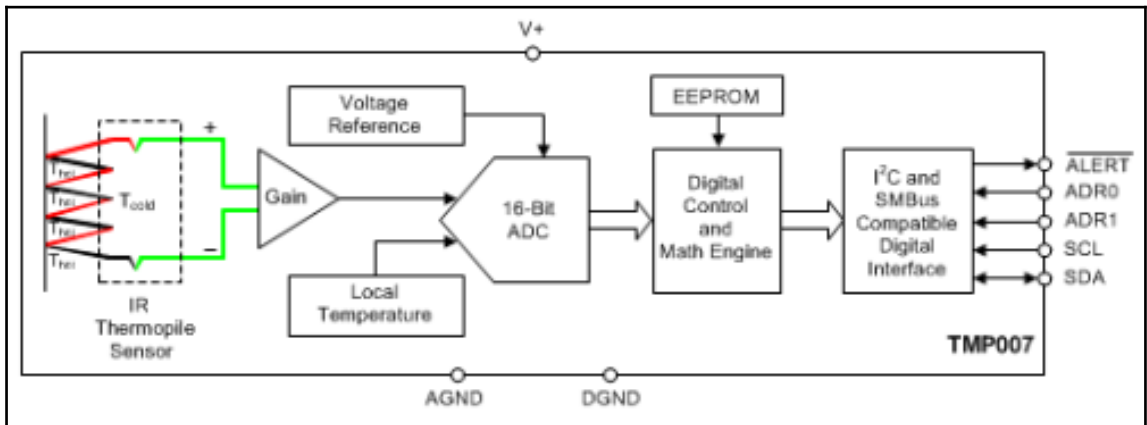
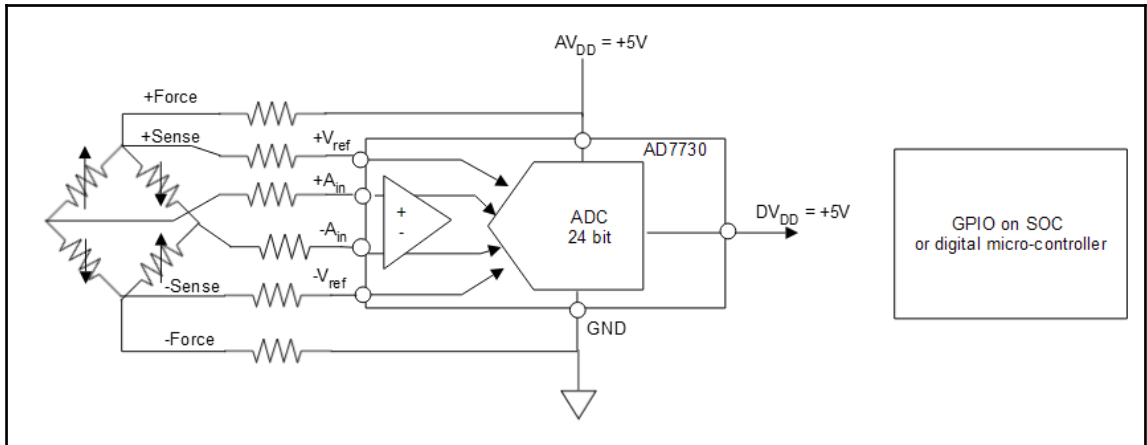


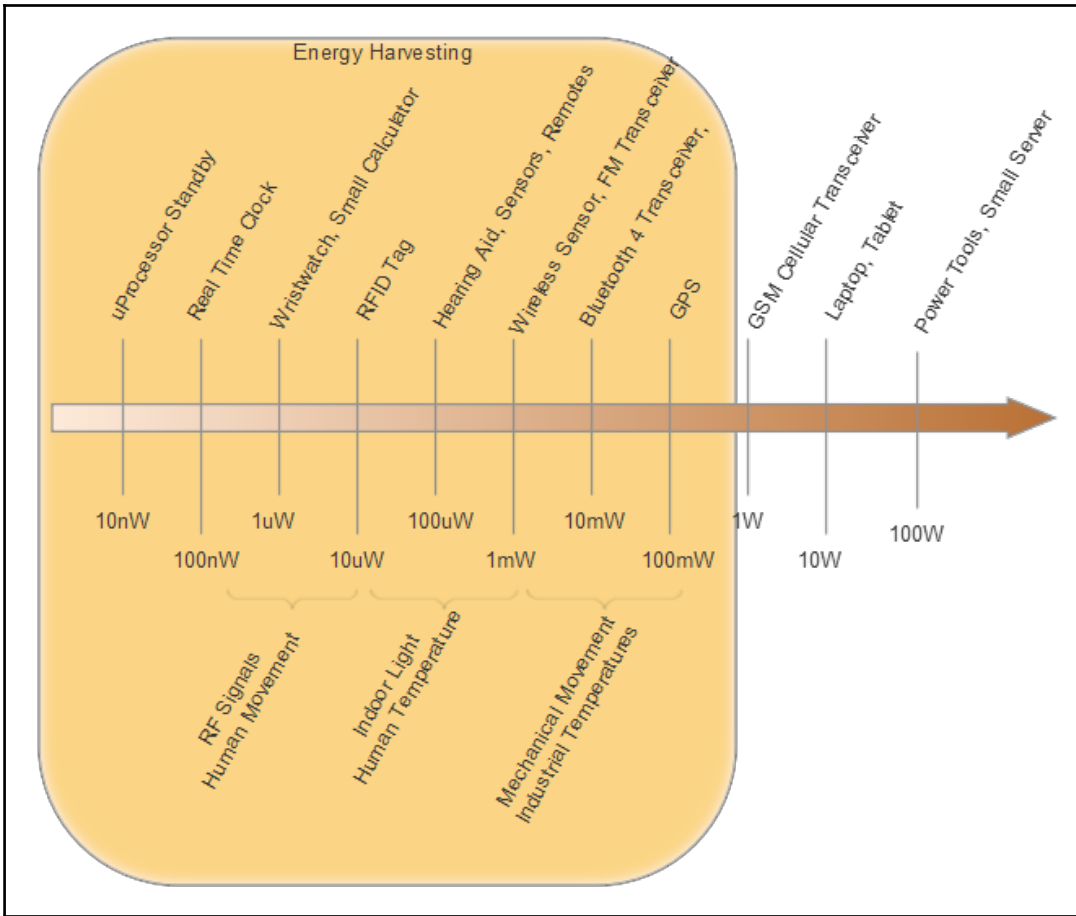


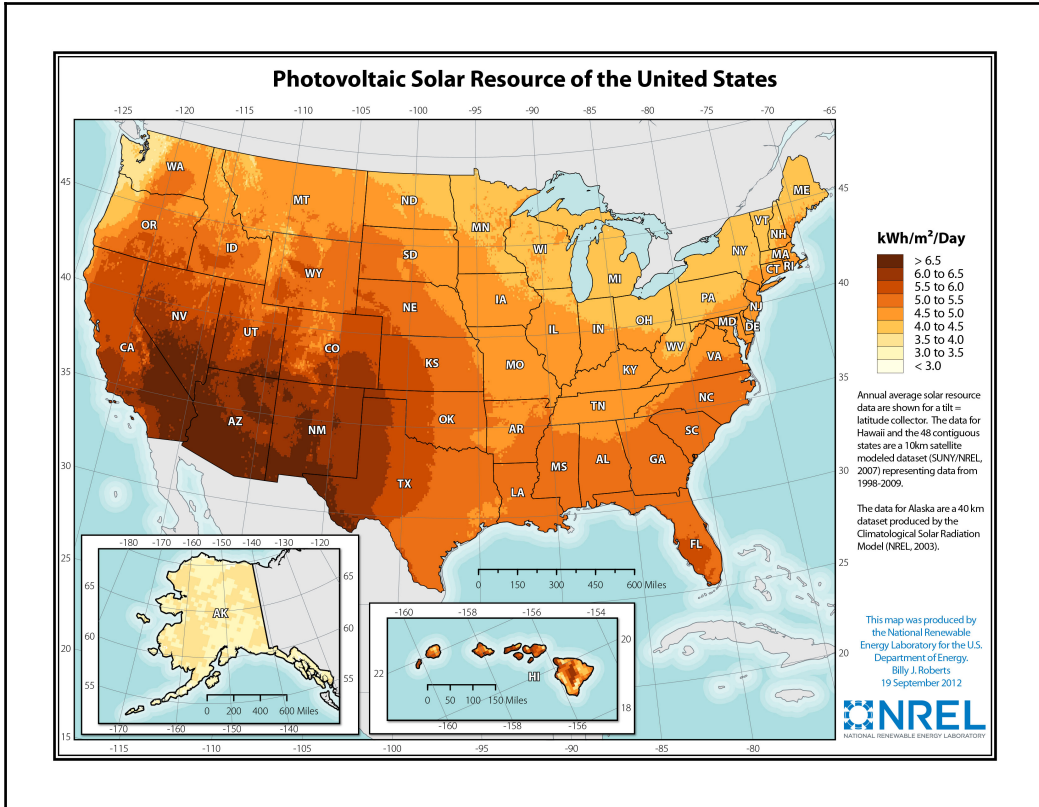
$$x_3 = (\sigma_1^{-2} + \sigma_2^{-2})^{-1} (\sigma_1^{-2} x_1 + \sigma_2^{-2} x_2)$$









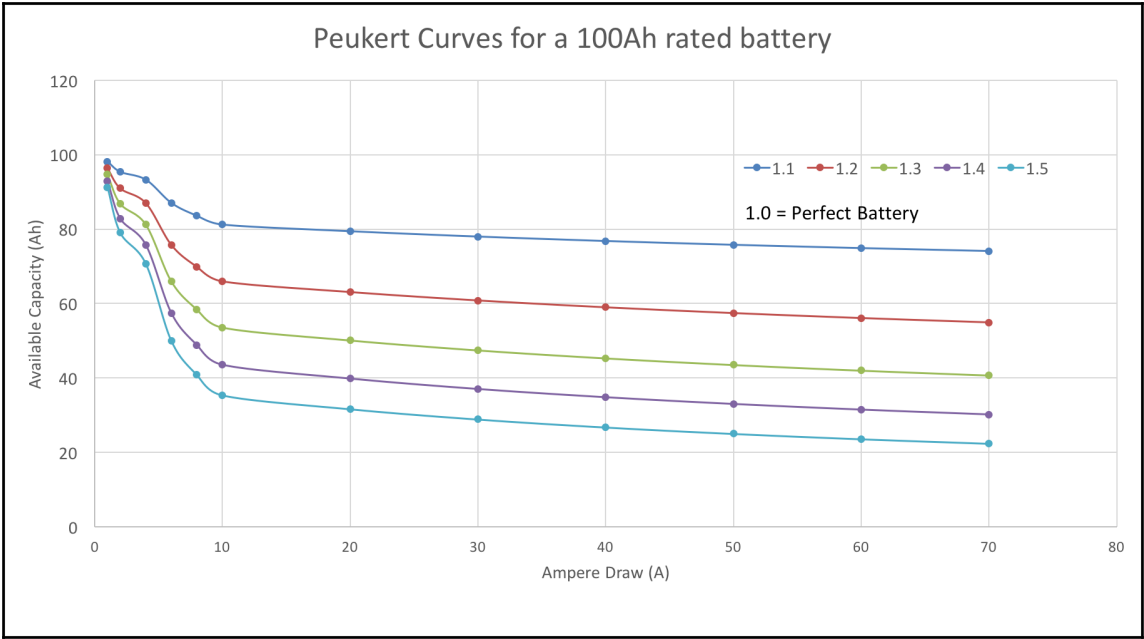


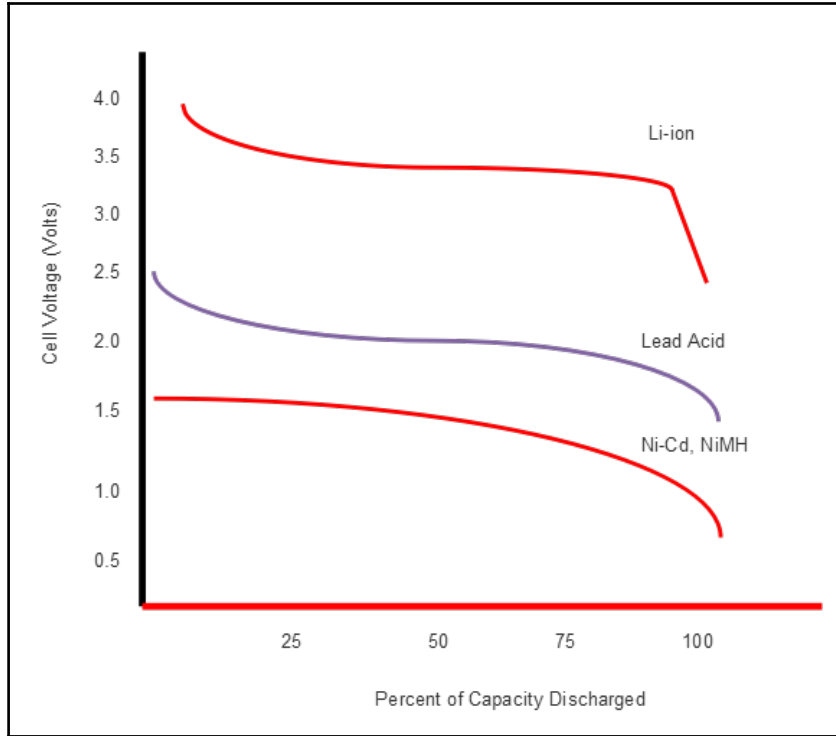
$$E = \frac{1}{2} QV^2 = \frac{Q^2}{2C}$$

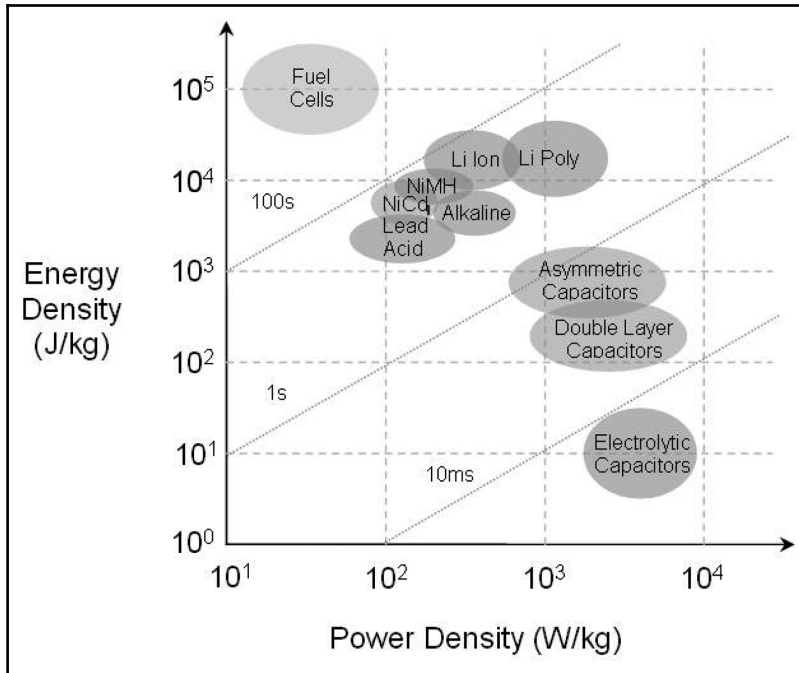
$$C = \epsilon_0 L_w / d$$

$$V = \int_{T_L}^{T_H} S_1(T) - S_2(T) dT$$

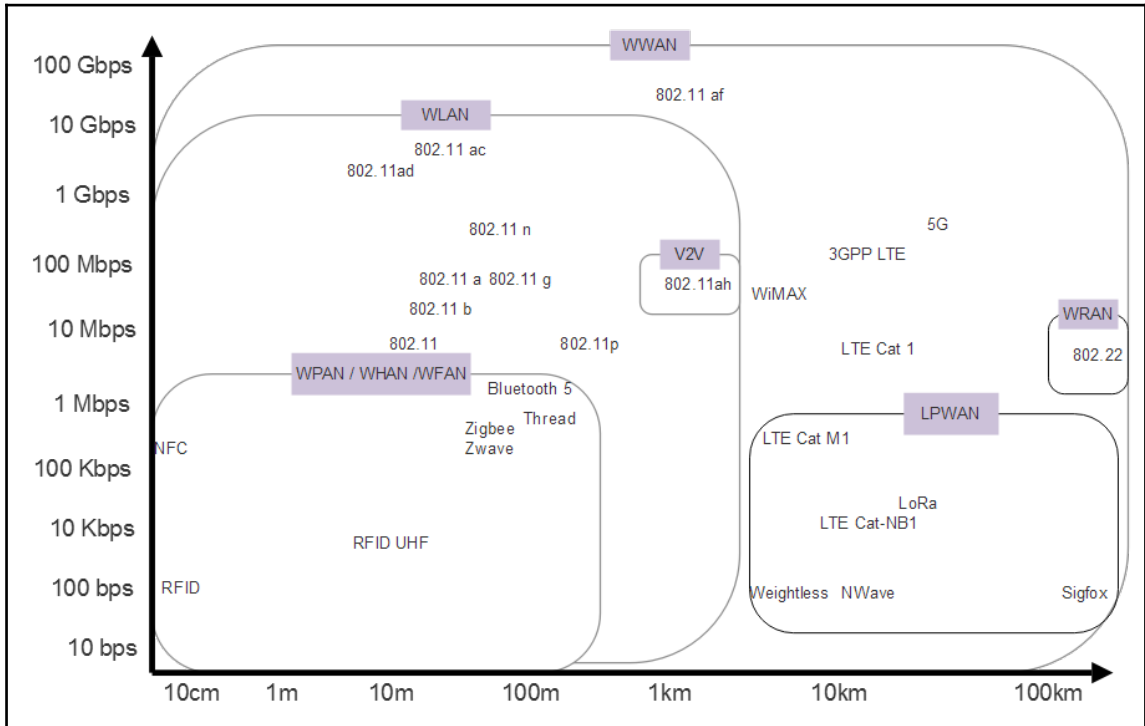
$$t = \frac{C_p}{I^n}$$





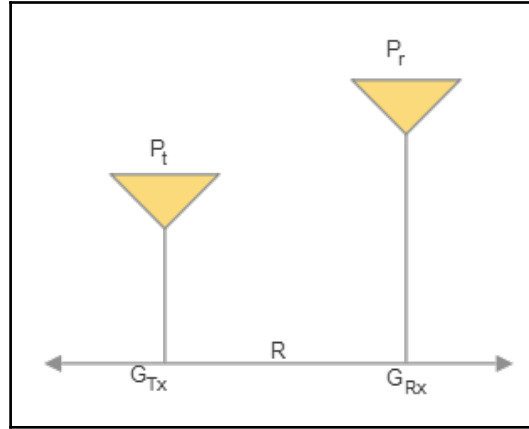


Chapter 4: Communications and Information Theory



$$P_r = P_t G_{Tx} G_{Rx} \frac{\lambda^2}{(4\pi R)^2}$$

$$P_r = P_t + G_{Tx} + G_{Rx} + 20 \log_{10} \left(\frac{\lambda}{4\pi R} \right)$$

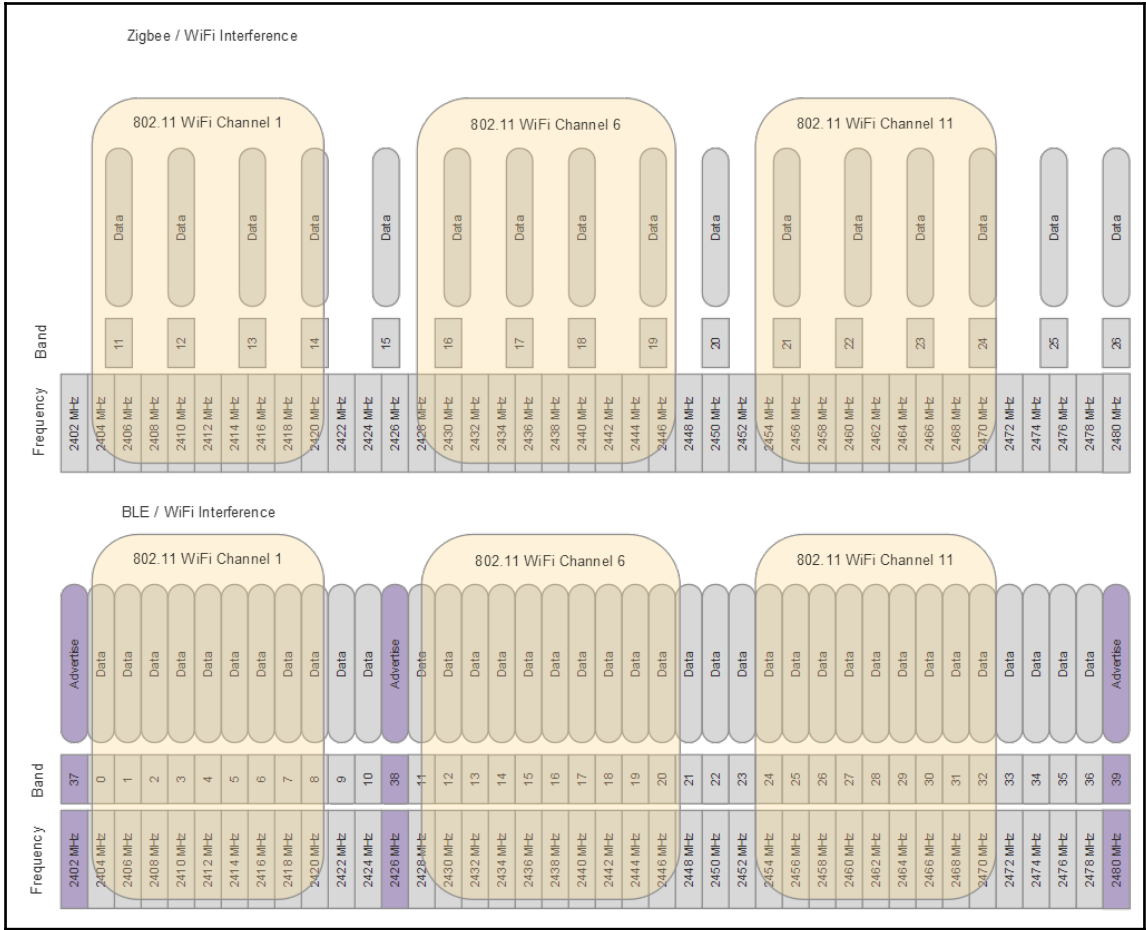


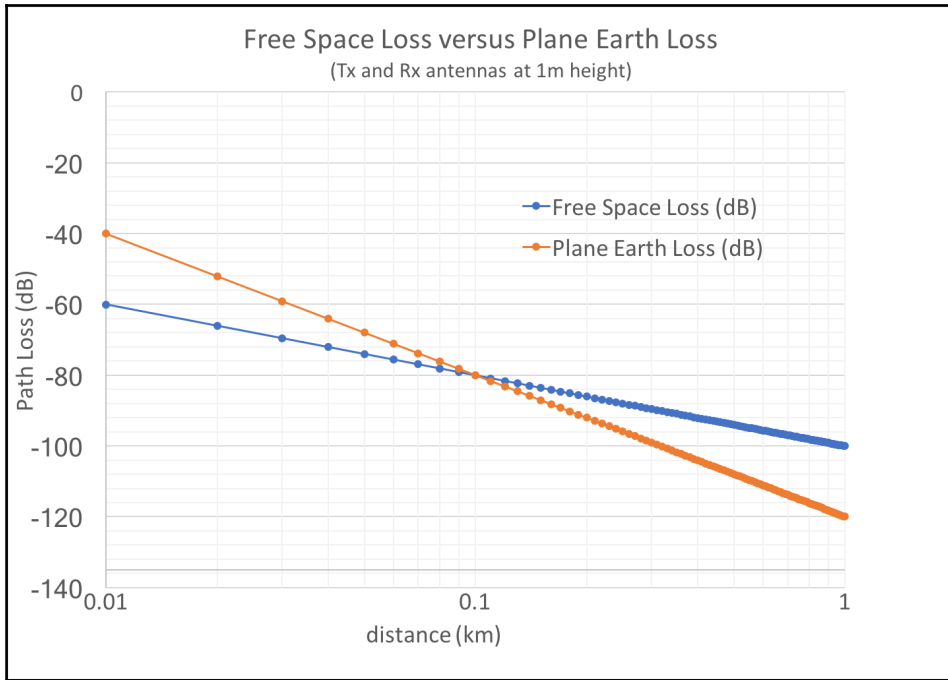
$$LinkBudget = \frac{Tx\ Power}{Rx\ sensitivity\ level}$$

$$Receiver\ Power(dB) = Transmitted\ Power(dB) + Gains(dB) - Losses(dB)$$

$$\begin{aligned} FSPL(dB) &= 10\log_{10} \left(\left(\frac{4\pi Rf}{c} \right)^2 \right) \\ &= 20\log_{10} \left(\frac{4\pi Rf}{c} \right) \\ &= 20\log_{10} (R) + 20\log_{10} (f) + 20\log_{10} \left(\frac{4\pi}{c} \right) \\ &= 20\log_{10} (R) + 20\log_{10} (f) - 147.55 \end{aligned}$$

$$\frac{P_r}{P_t} = L_{plane\ earth\ loss} \approx \left(\frac{\lambda}{4\pi R} k \frac{2h_t h_r}{R} \right) \approx \frac{h_t^2 h_r^2}{R^4} \text{ where } k = \frac{2\pi}{\lambda}$$





$$f_p \leq 2B$$

$$M = 1 + \frac{A}{\Delta V}$$

$$R = f_p \log_2(M)$$

$$R \leq 2B \log_2(M)$$

$$C = B \log_2\left(1 + \frac{S}{N}\right)$$

$$C = B \times n \times \log_2\left(1 + \frac{S}{N}\right)$$

$$C = B \log_2 \left(1 + \frac{S}{N} \right)$$

$$200 = 5000 \times \log_2 \left(1 + \frac{S}{N} \right)$$

$$\frac{S}{N} = 0.028$$

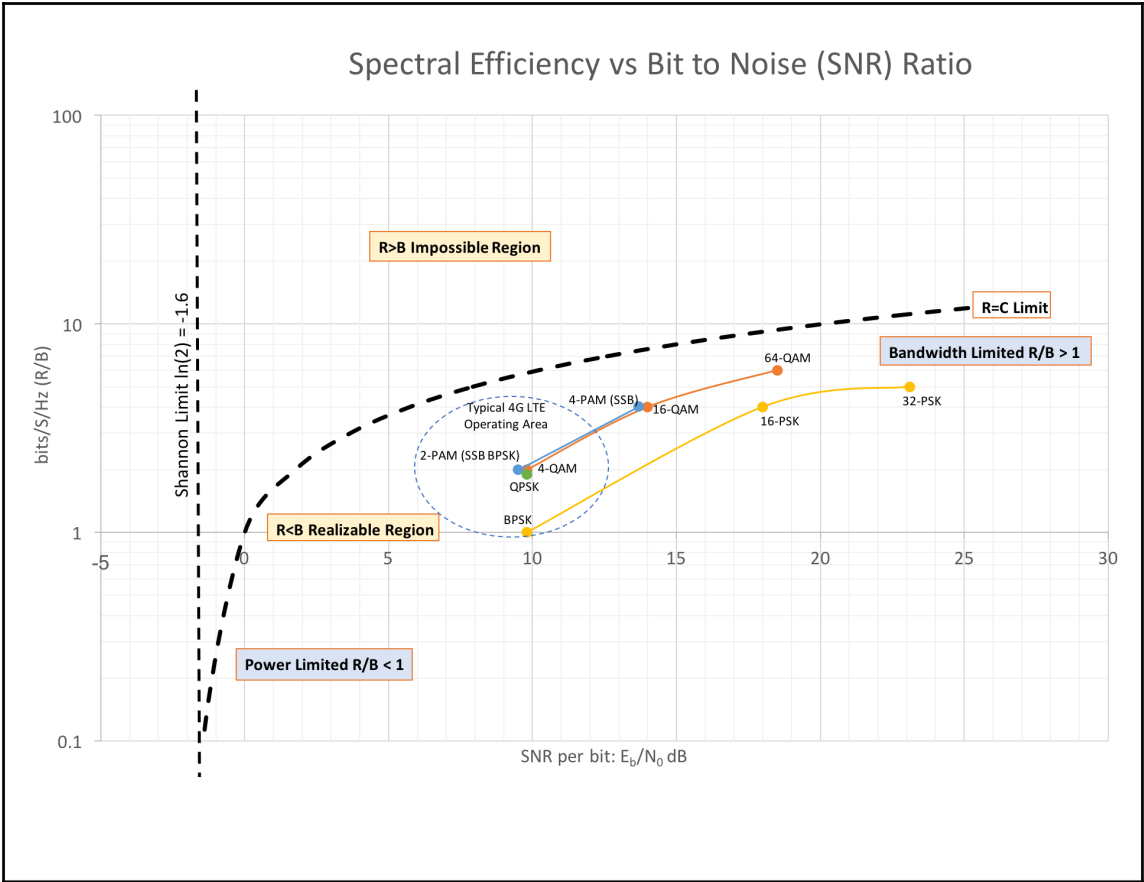
$$\frac{S}{N} = -15.528 \text{ dB}$$

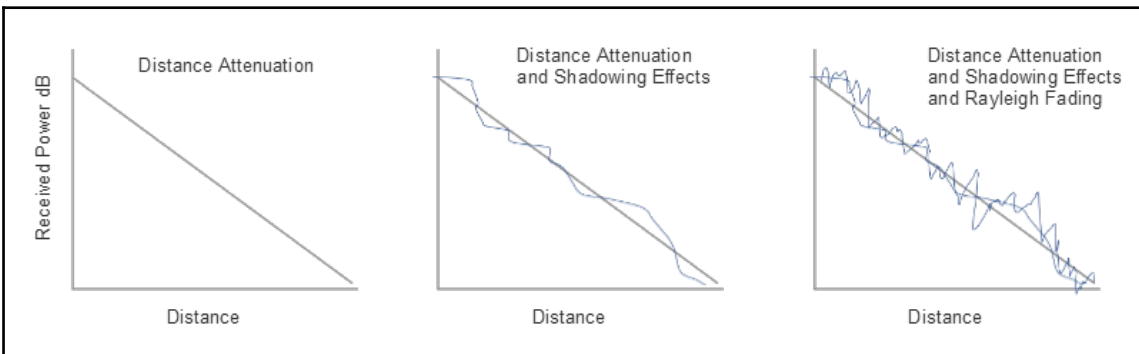
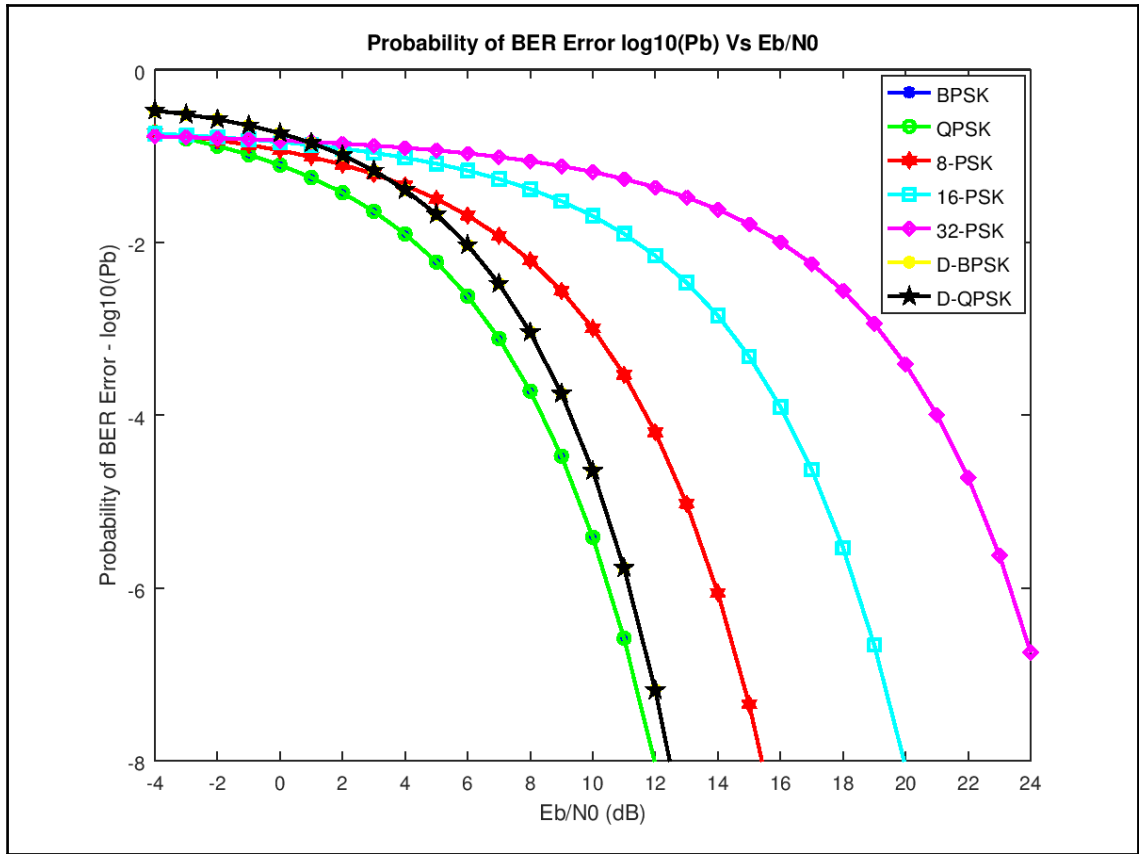
$$\frac{C}{B} = \log_2 \left(1 + \frac{E_b C}{N_0 B} \right)$$

$$\frac{E_b}{N_0} = \frac{2^{\frac{C}{B}} - 1}{\frac{C}{B}}$$

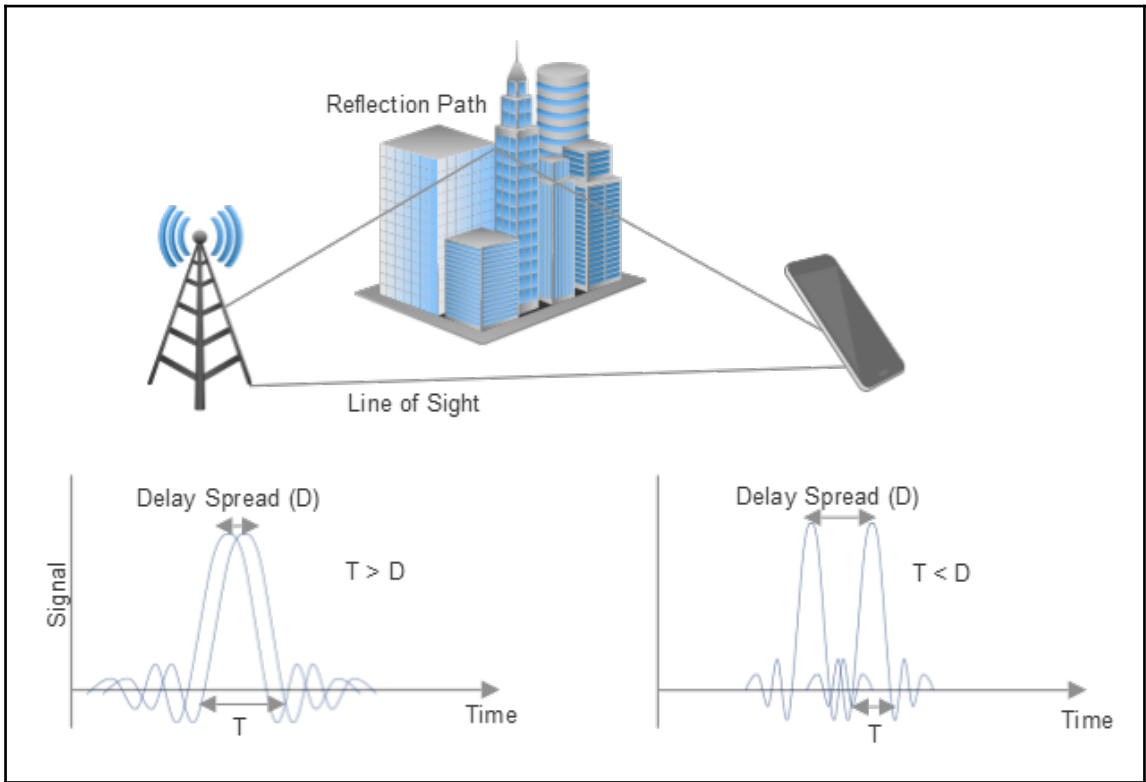
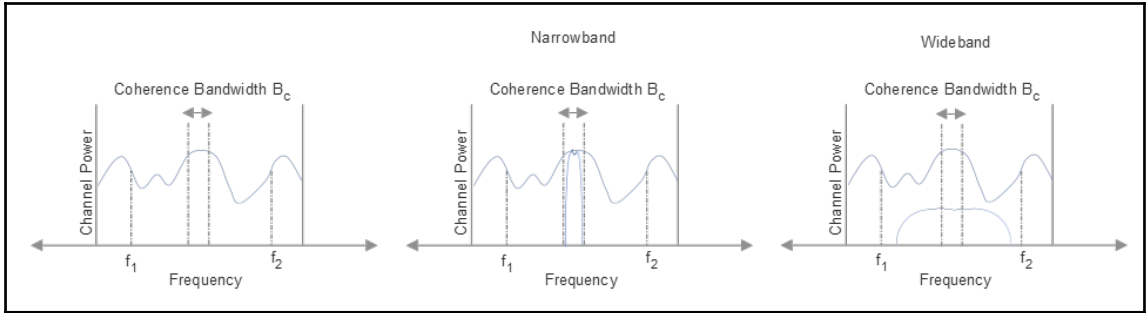
$$\frac{E_b}{N_0} \geq \lim_{\frac{C}{B} \rightarrow 0} \frac{2^{\frac{C}{B}} - 1}{\frac{C}{B}} = \ln(2) = -1.59 \text{ dB}$$

Spectral Efficiency vs Bit to Noise (SNR) Ratio

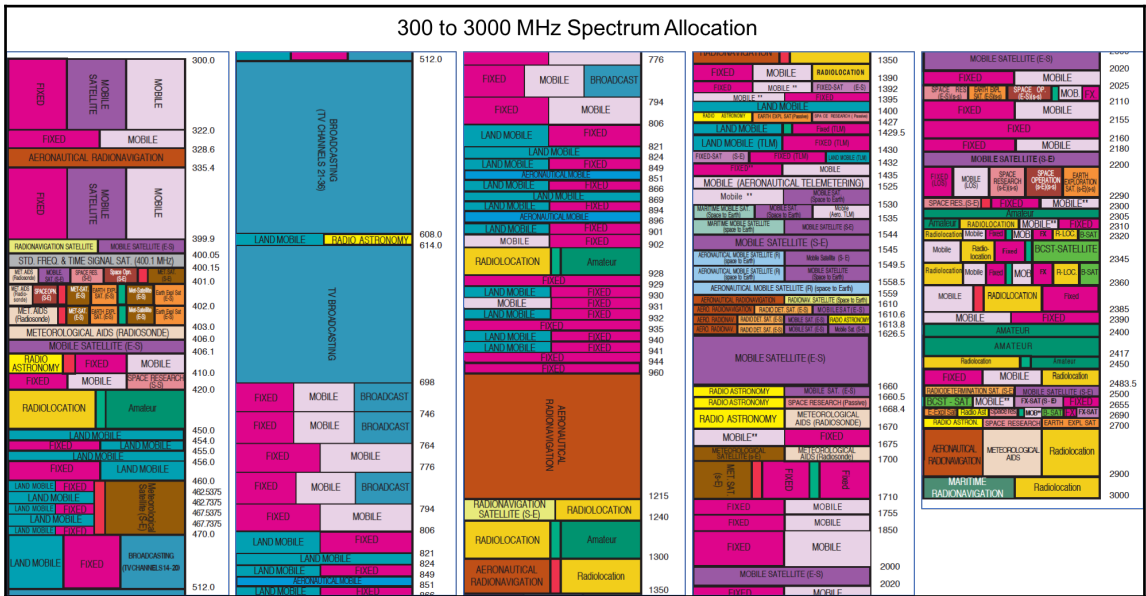
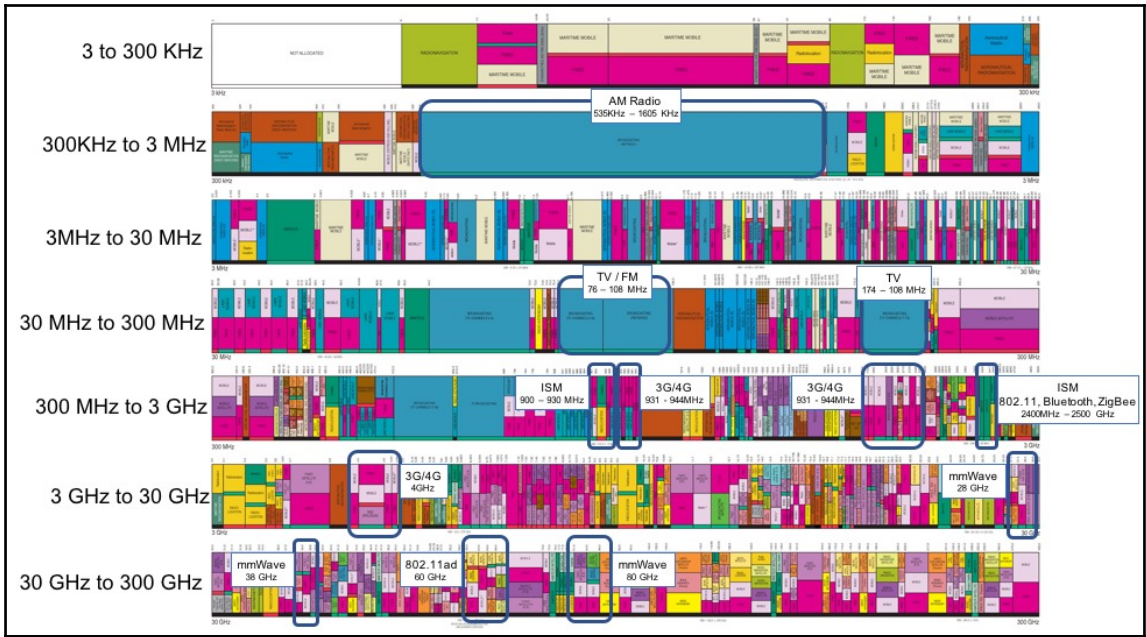




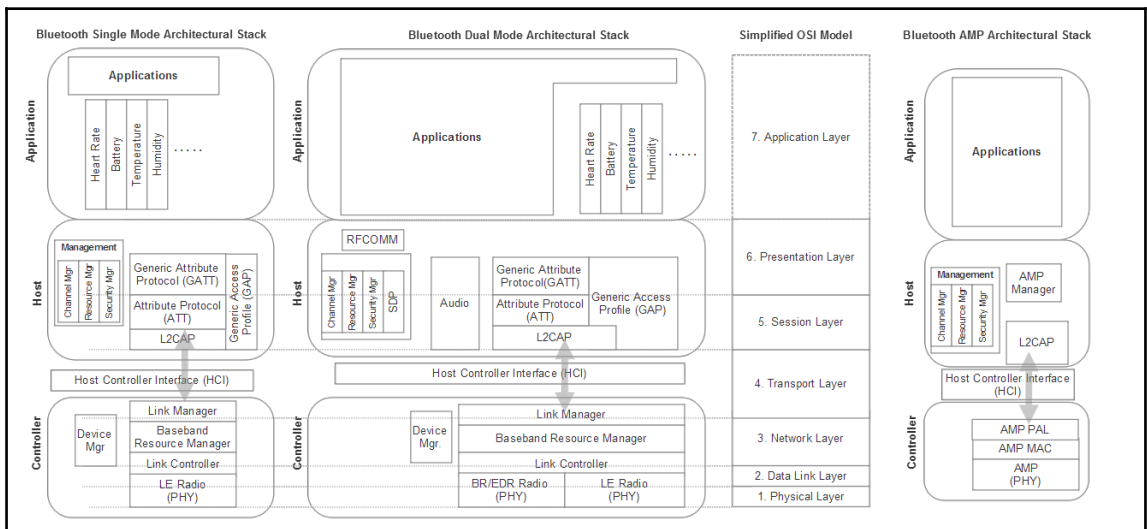
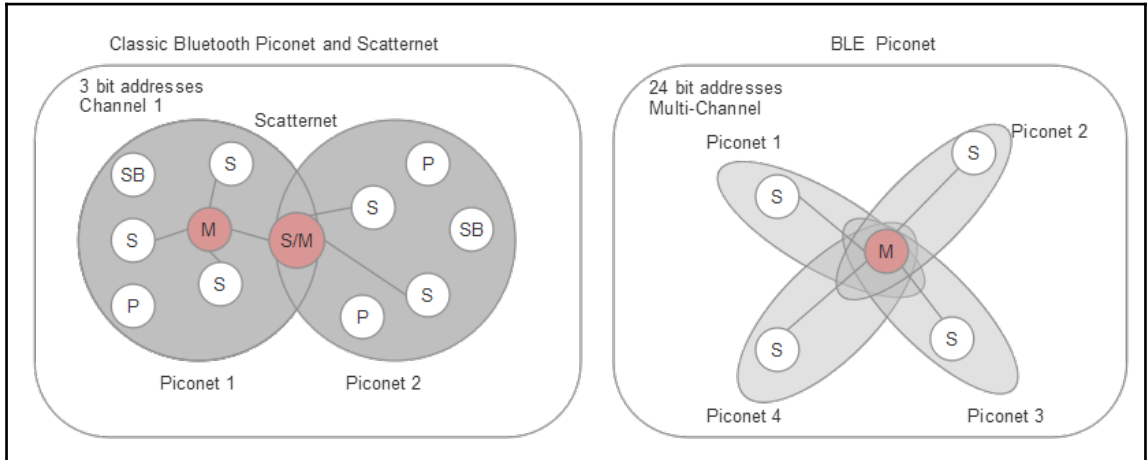
$$B_c \approx \frac{1}{D}$$



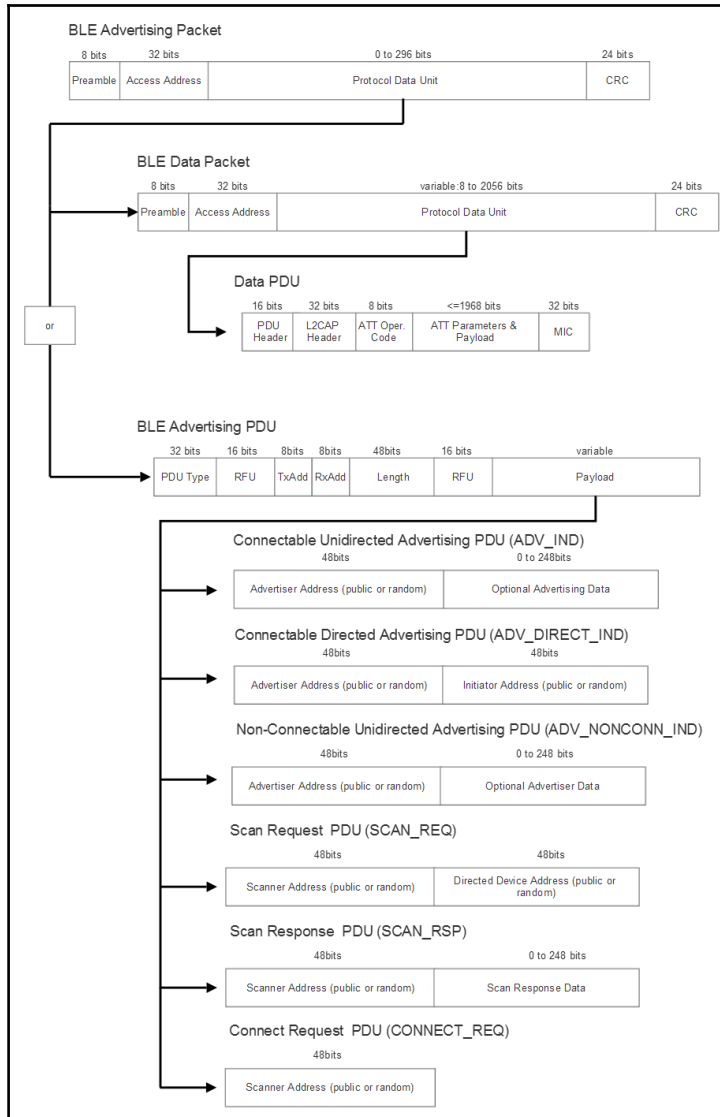
Frequency	IEEE Band	European Union, NATO, US ECM	ITU	
			ITU Band	ITU Abbreviation
0.3 Hz				
3 Hz		A	1	ELF
30 Hz			2	SLF
300 Hz			3	ULF
3 kHz			4	VLF
30 kHz			5	LF
300 kHz			6	MF
3 MHz	HF		7	HF
30 MHz	VHF	B	8	VHF
250 MHz			9	UHF
300 MHz	UHF			
500 MHz				
1 GHz	L	D	10	SHF
2 GHz	S	E		
3 GHz		F		
4 GHz	C	G		
6 GHz		H		
8 GHz	X	I		
10 GHz		J		
12 GHz	Ku			
18 GHz	K			
20 GHz				
27 GHz	Ka	K	12	THF
30 GHz				
40 GHz	V	L		
60 GHz		M		
75 GHz	W			
100 GHz				
110 GHz	mm			
300 GHz				
3 THz				

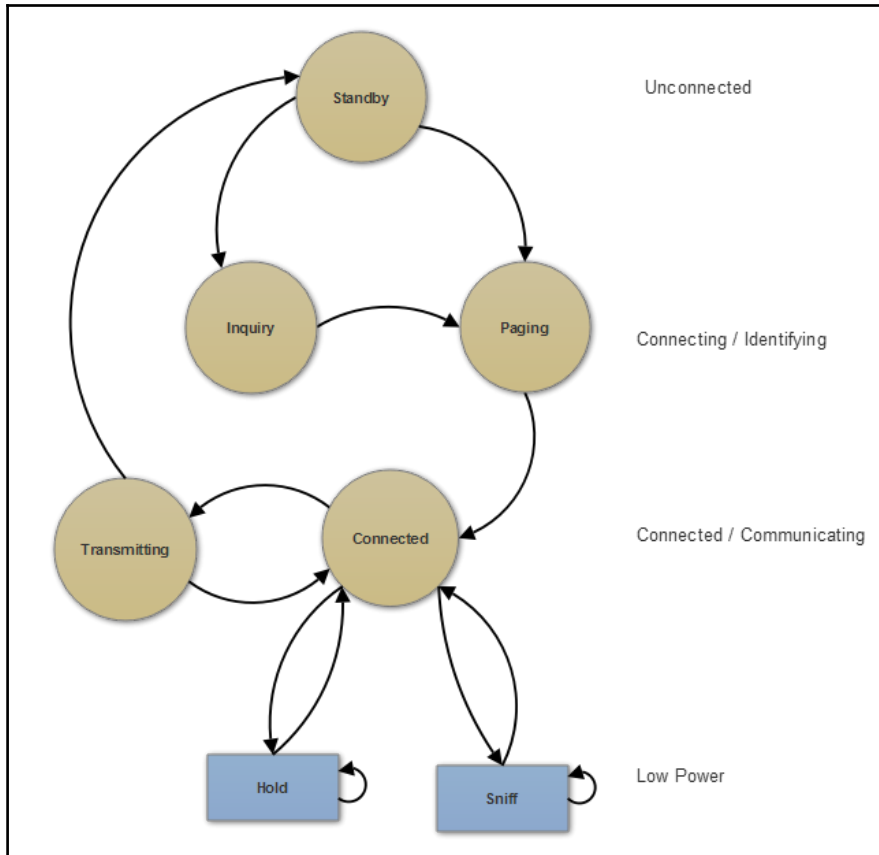


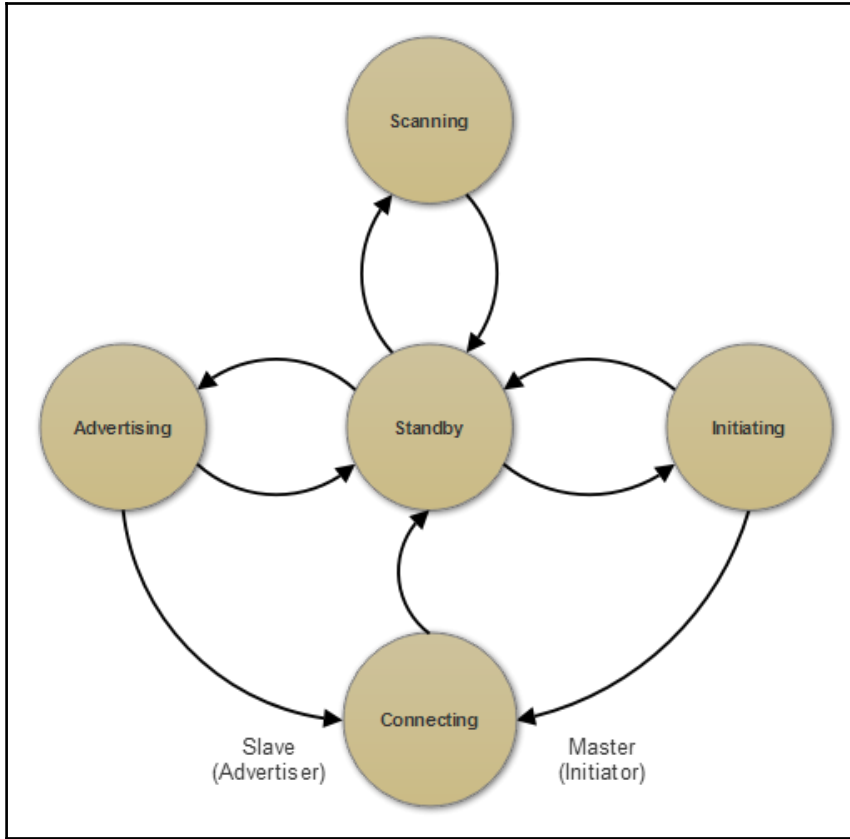
Chapter 5: Non-IP Based WPAN

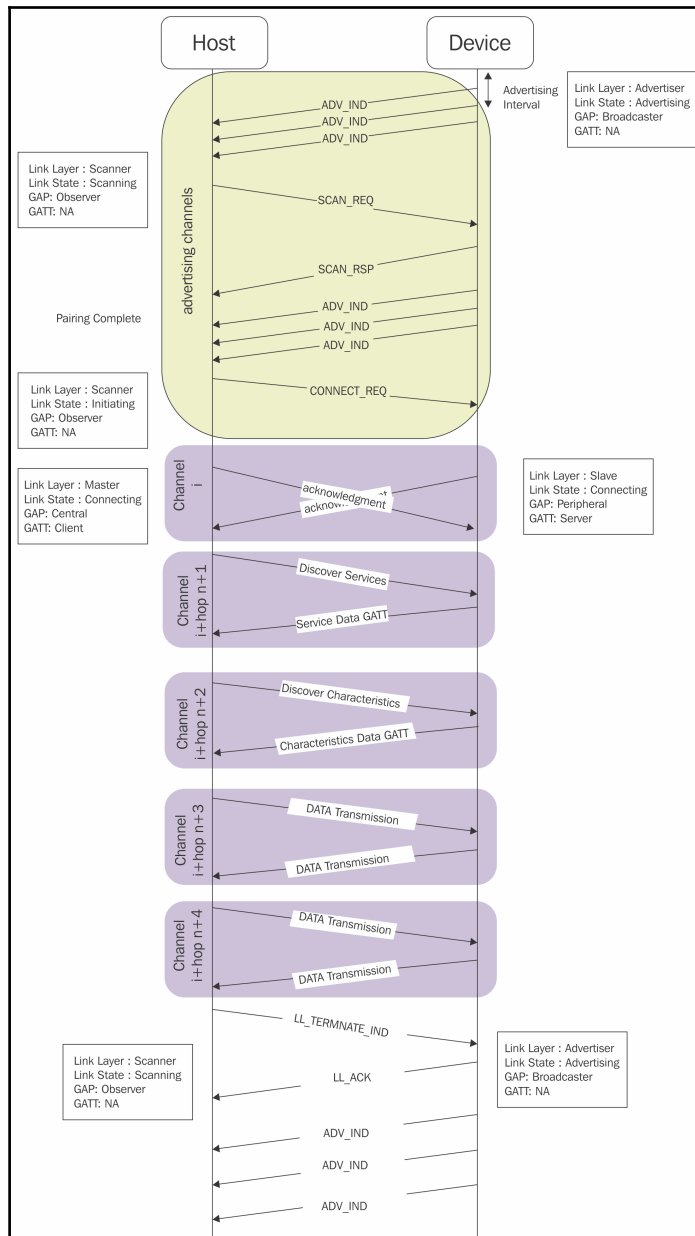


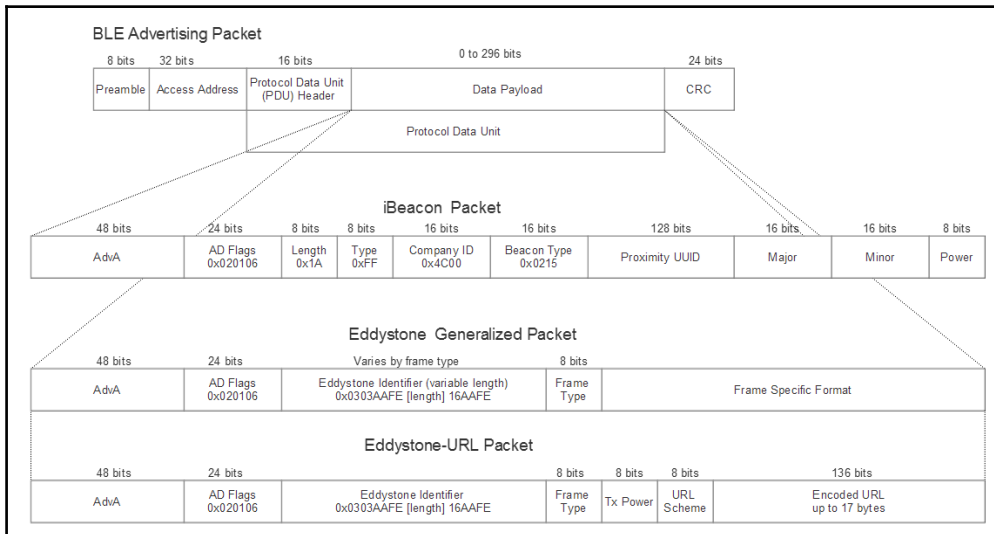
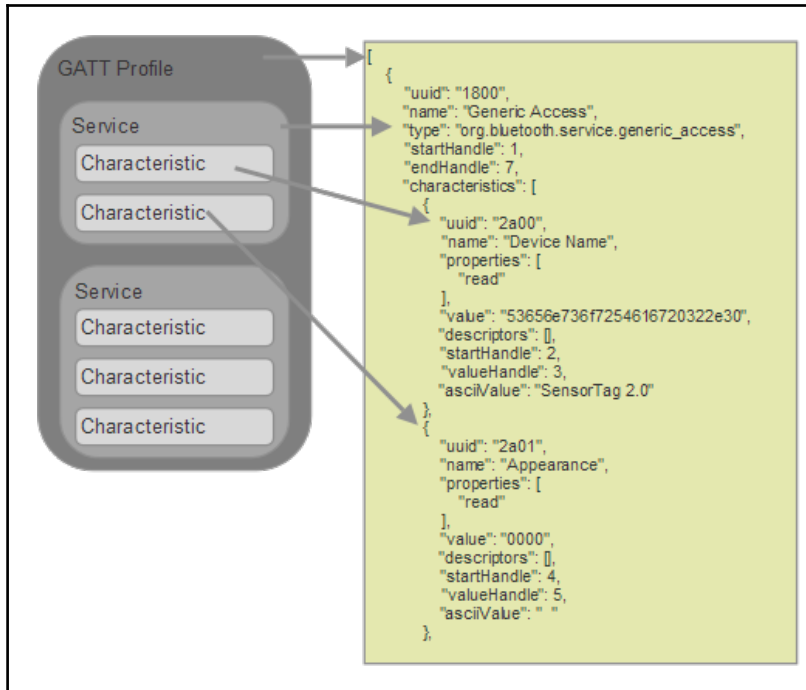
Frequency	Band	
2402 MHz	37	Advertise
2404 MHz	0	Data
2406 MHz	1	Data
2408 MHz	2	Data
2410 MHz	3	Data
2412 MHz	4	Data
2414 MHz	5	Data
2416 MHz	6	Data
2418 MHz	7	Data
2420 MHz	8	Data
2422 MHz	9	Data
2424 MHz	10	Data
2426 MHz	38	Advertise
2428 MHz	11	Data
2430 MHz	12	Data
2432 MHz	13	Data
2434 MHz	14	Data
2436 MHz	15	Data
2438 MHz	16	Data
2440 MHz	17	Data
2442 MHz	18	Data
2444 MHz	19	Data
2446 MHz	20	Data
2448 MHz	21	Data
2450 MHz	22	Data
2452 MHz	23	Data
2454 MHz	24	Data
2456 MHz	25	Data
2458 MHz	26	Data
2460 MHz	27	Data
2462 MHz	28	Data
2464 MHz	29	Data
2466 MHz	30	Data
2468 MHz	31	Data
2470 MHz	32	Data
2472 MHz	33	Data
2474 MHz	34	Data
2476 MHz	35	Data
2478 MHz	36	Data
2480 MHz	39	Advertise

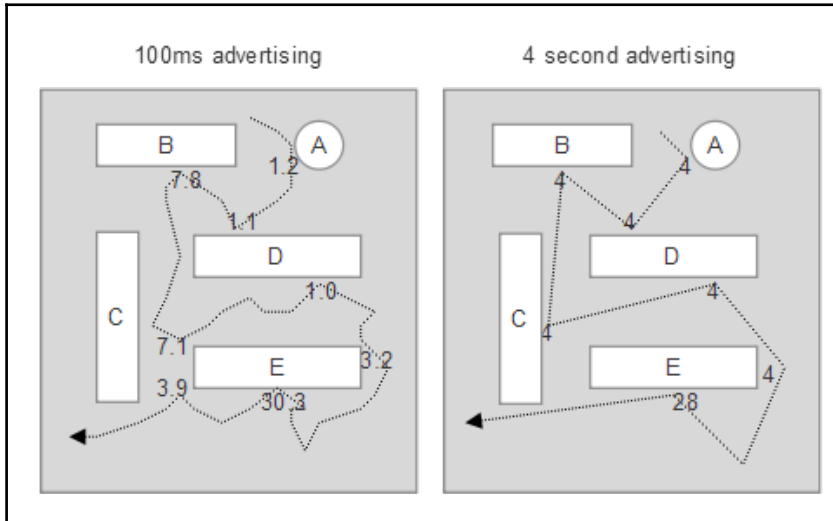
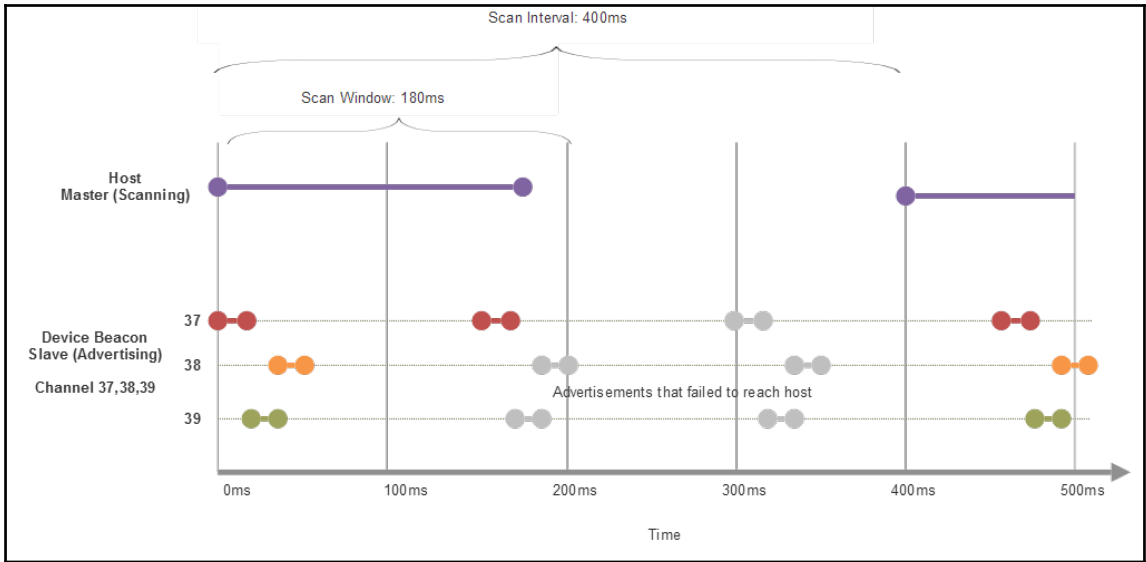


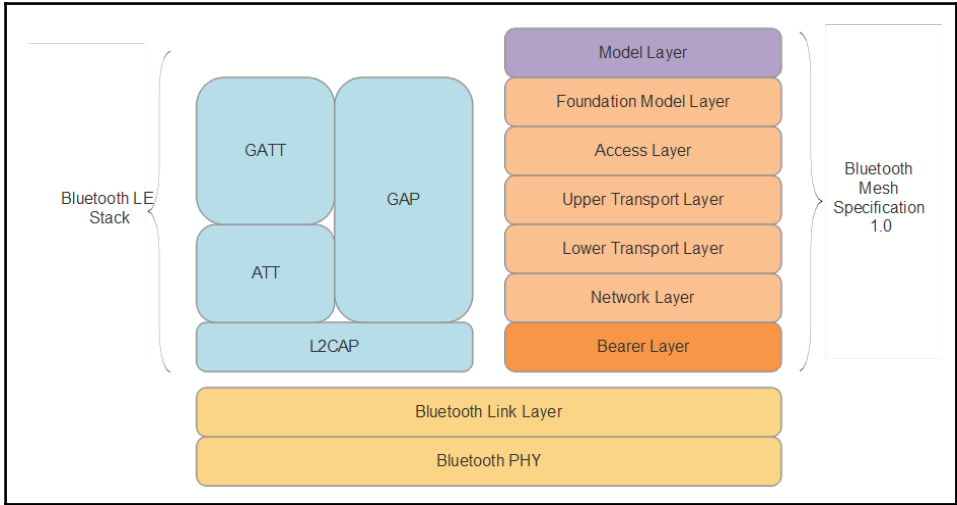
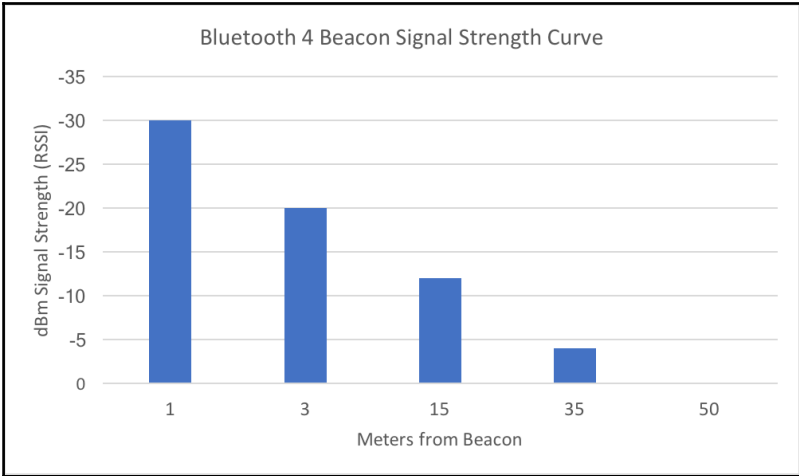


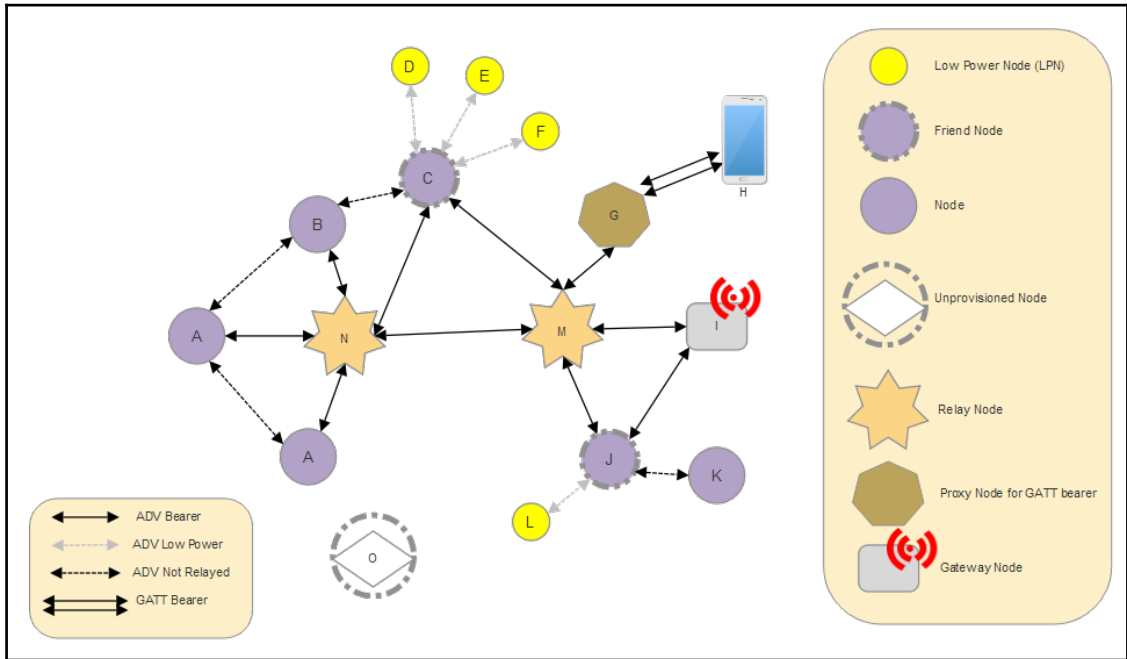
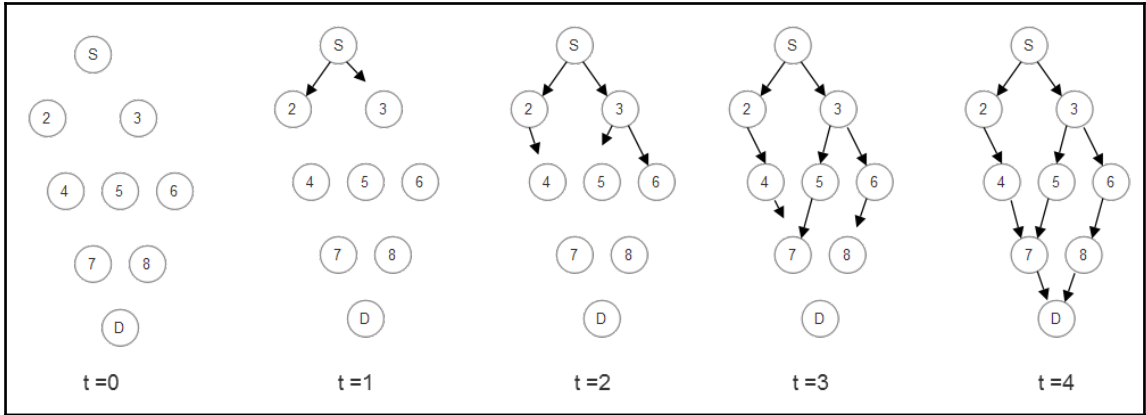


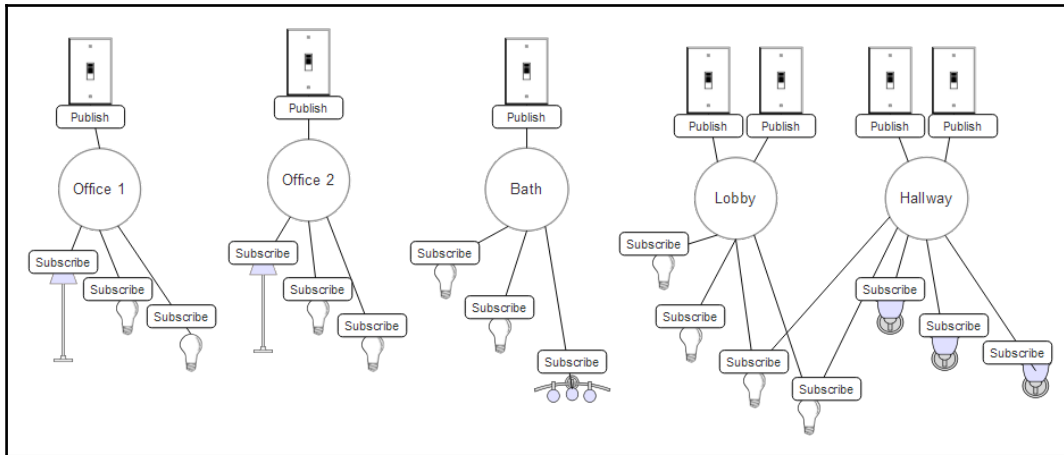






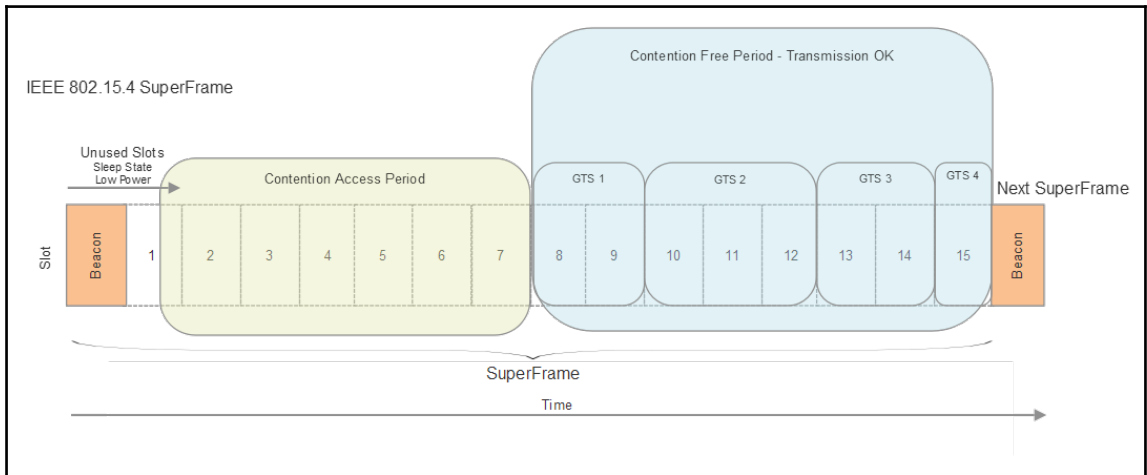
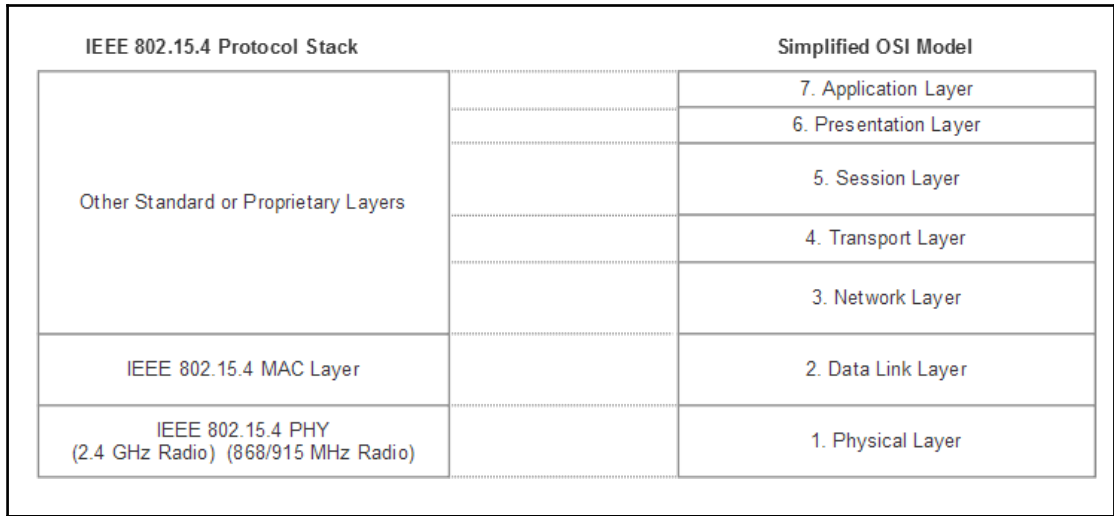


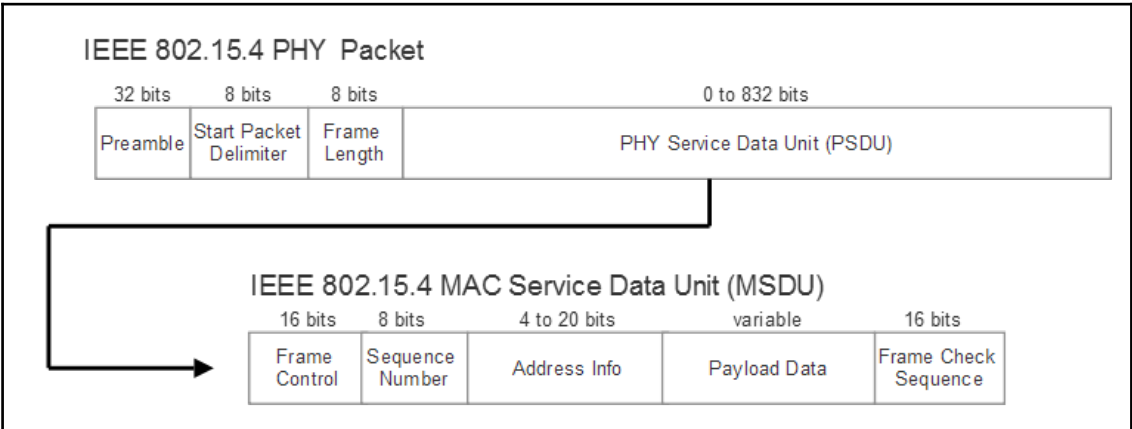
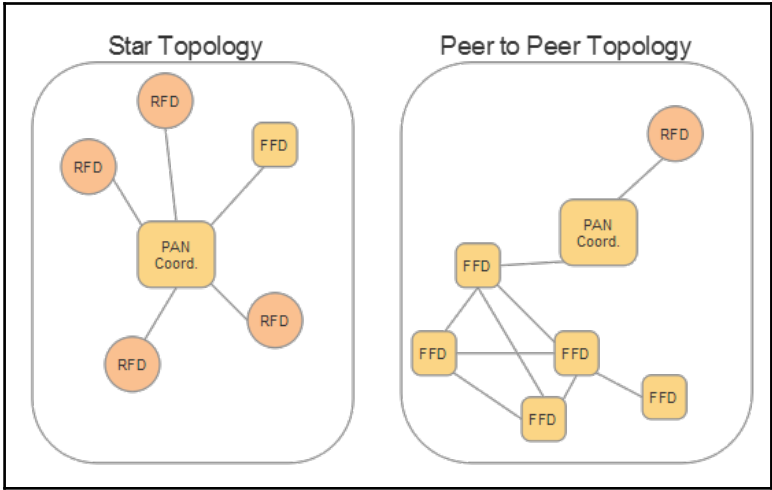


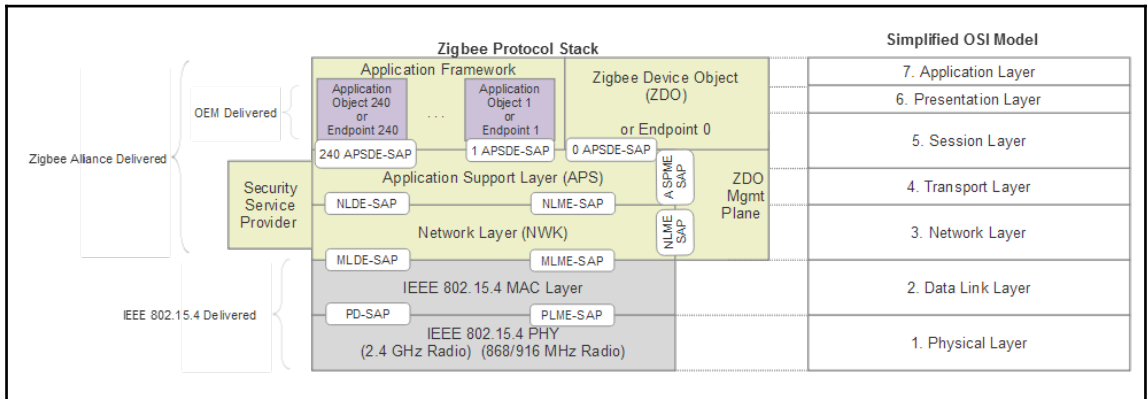
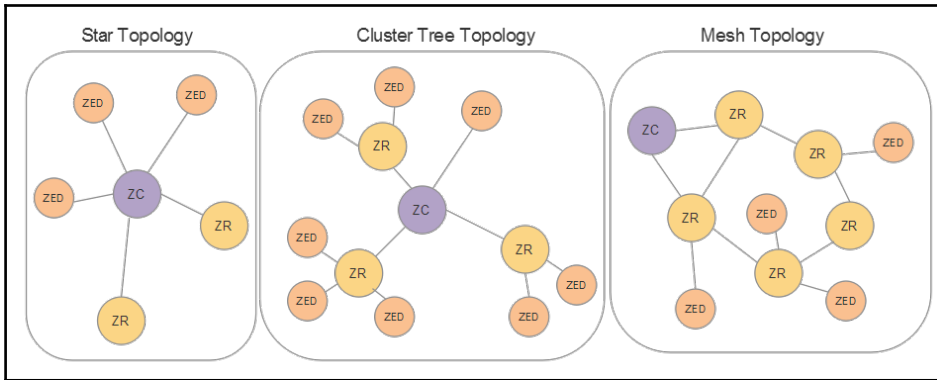


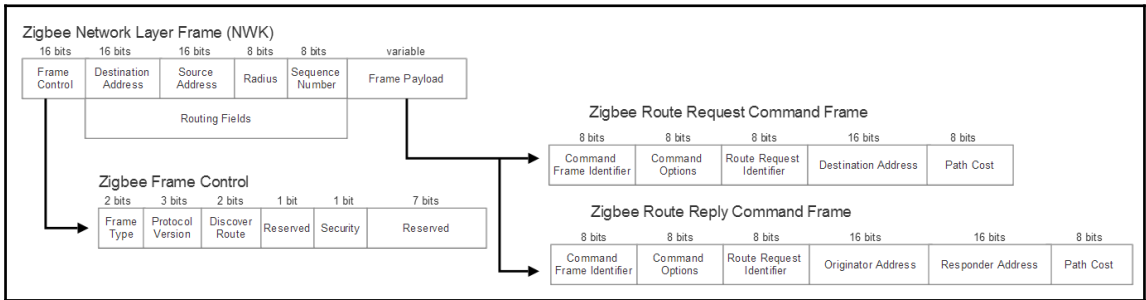
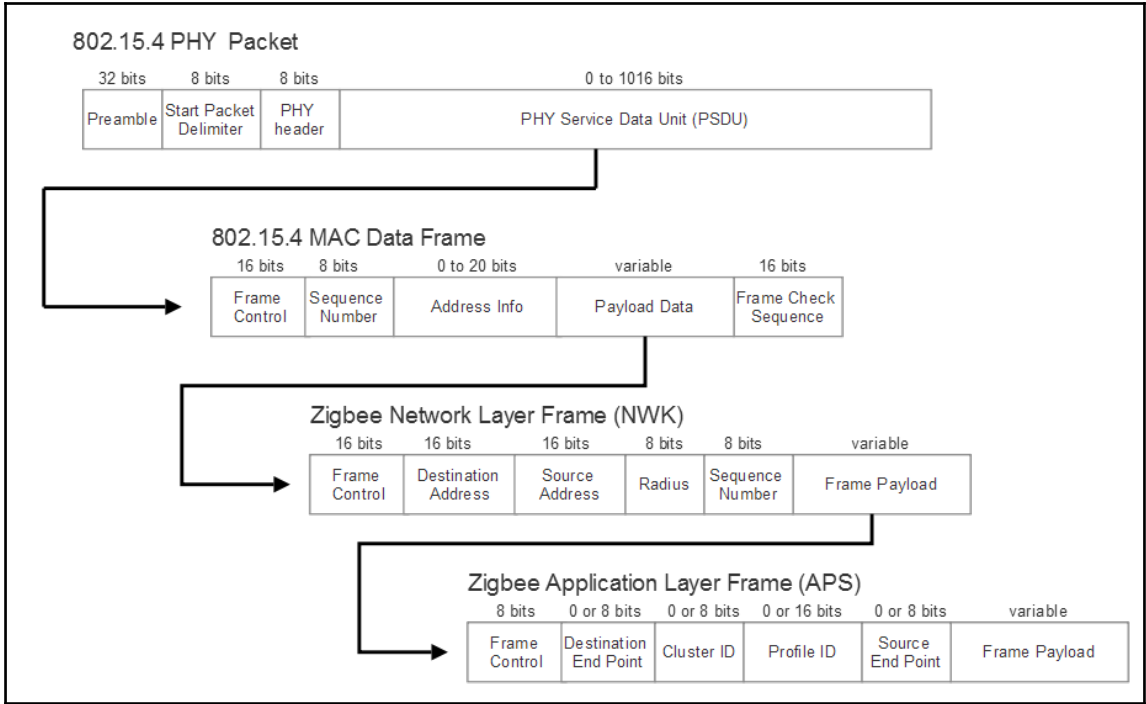
868 MHz Band		915 MHz Band	
Central Frequency	Channel	Central Frequency	Channel
868 MHz	0	908 MHz	1
		908 MHz	2
		910 MHz	3
		912 MHz	4
		914 MHz	5
		916 MHz	6
		918 MHz	7
		920 MHz	8
		922 MHz	9
		924 MHz	10

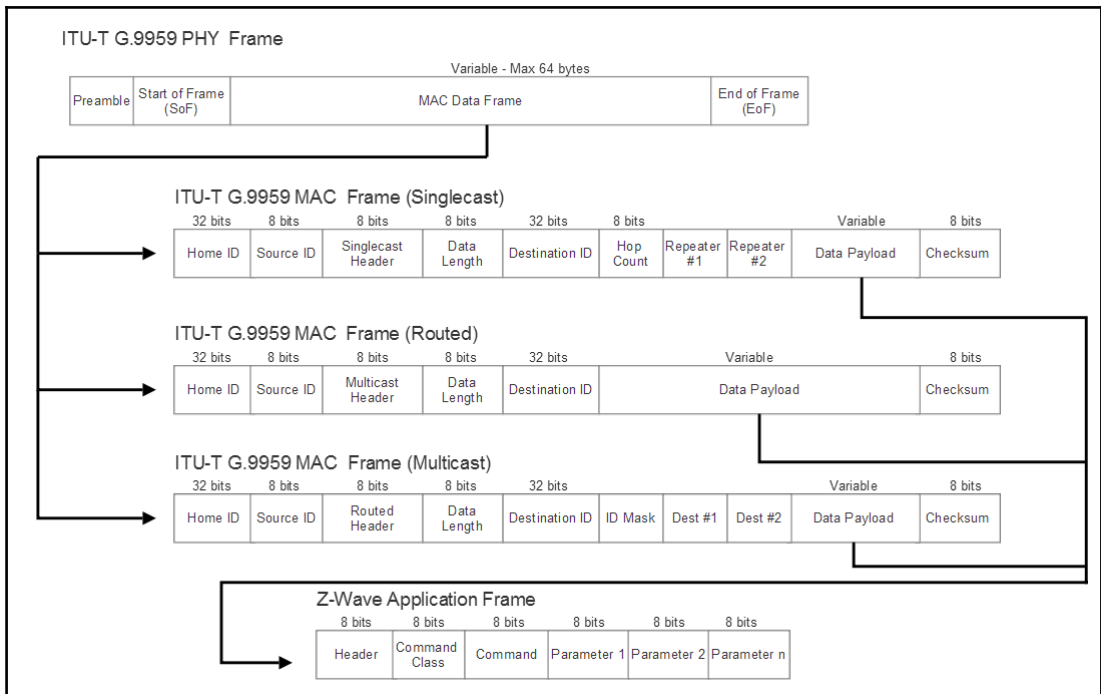
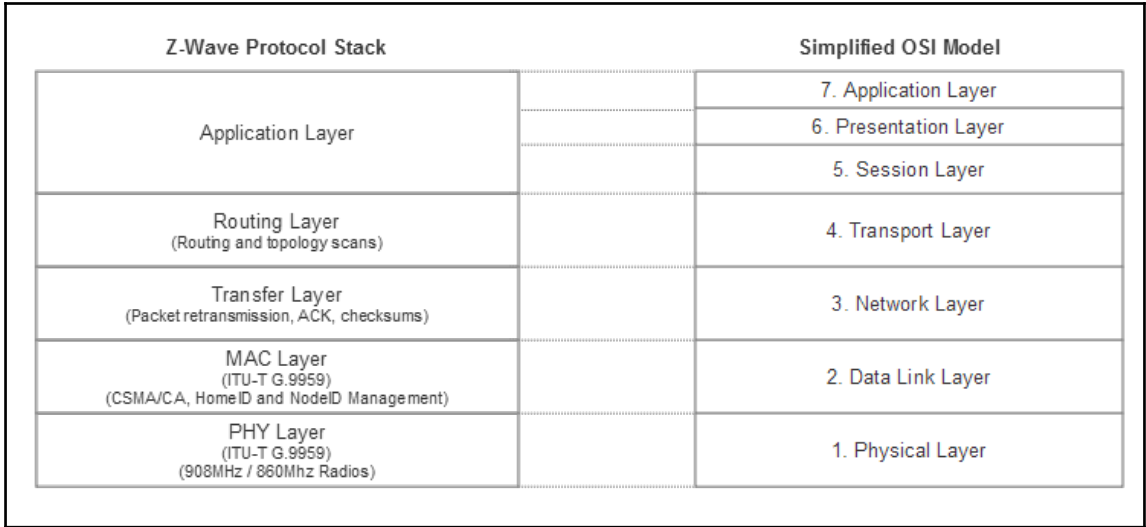
2.4 GHz Band	
Central Frequency	Channel
2405 MHz	11
2410 MHz	12
2415 MHz	13
2420 MHz	14
2425 MHz	15
2430 MHz	16
2435 MHz	17
2440 MHz	18
2445 MHz	19
2450 MHz	20
2455 MHz	21
2460 MHz	22
2465 MHz	23
2470 MHz	24
2475 MHz	25
2480 MHz	26

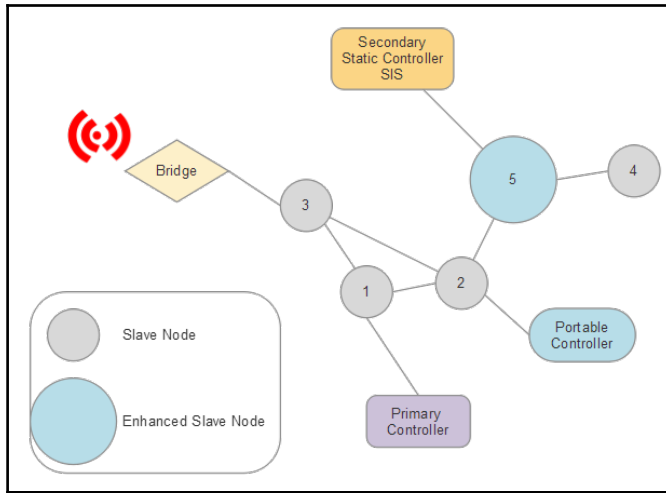










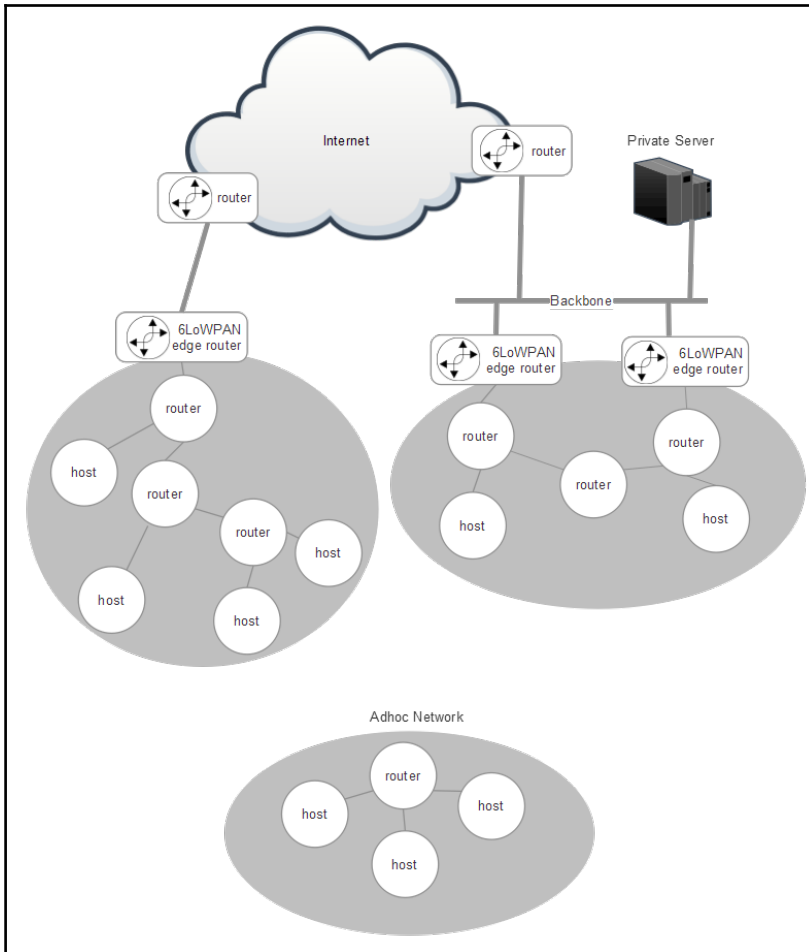


	Slave 1	Slave 2	Slave 3	Slave 4	Enhanced Slave 5	Primary Controller	Secondary SIS	Bridge	Portable Controller
Slave 1	0	1	1	0	0	1	0	0	0
Slave 2	1	0	1	0	1	0	0	0	1
Slave 3	1	1	0	0	0	0	0	1	0
Slave 4	0	0	0	0	1	0	0	0	0
Enhanced Slave 5	0	1	0	1	0	0	1	0	0
Primary Controller	0	0	0	0	0	0	0	0	0
Secondary SIS	0	0	0	0	1	0	0	0	0
Bridge	1	0	1	0	0	0	0	0	0
Portable Controller	0	1	0	0	0	0	0	0	0

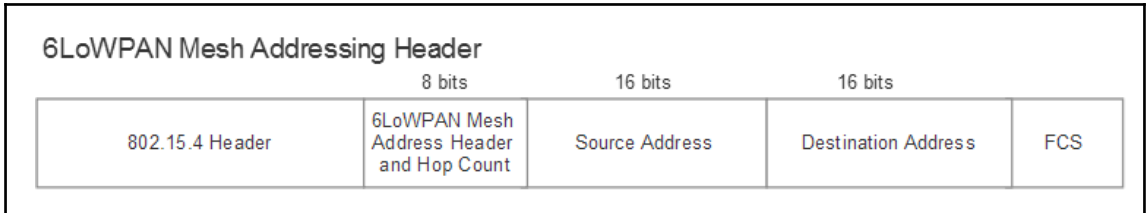
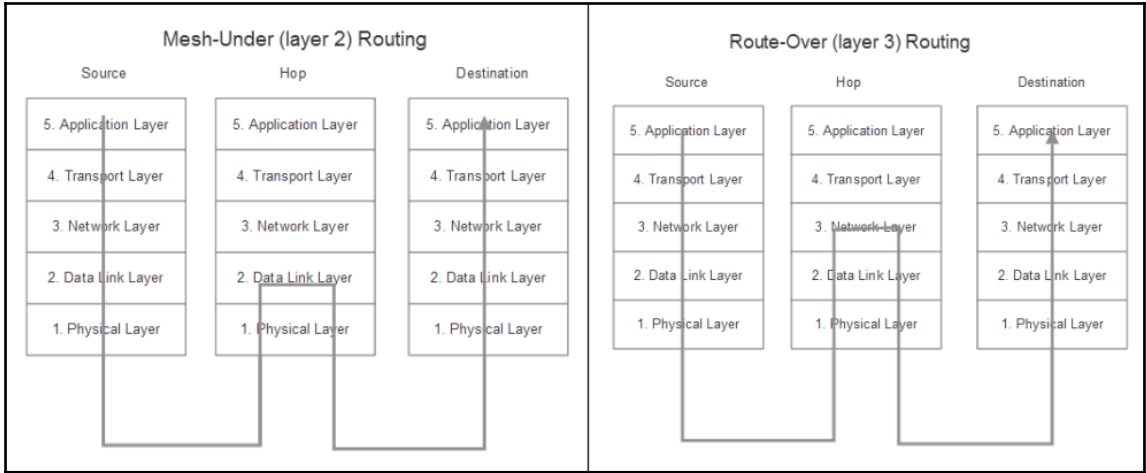
Chapter 6: IP-Based WPAN and WLAN

OSI (Open Source Interconnection) Model

Layers	Purpose / Function	Protocol Used	Fundamental Data Type
7. Application	User Application Layer: browser, ftp, app, etc. (remote file access, resource sharing, LDAP, SNMP)	SMTP FTP	Data
6. Presentation	Syntax Layer: encrypt, compress (optional) (data encrypt/decrypt, codec, translation)	JPEG, ASCII, ROT13	Data
5. Session Layer	Synchronization & Logical Port Routing (session establishment, start & terminate, security, logging, name recognition)	RPC, NFS, NetBIOS	Data
4. Transport Layer	TCP: Host to Host & Flow Control (end to end connections & reliability, message segmentation, acknowledgment, session multiplexing)	TCP / UDP	TCP: Segments UDP: Datagrams
3. Network Layer	Packets: IP Address (path determination, logical addressing, routing, traffic control, frame segmentation, subnet management)	IP, IPX, ICMP	Packets
2. Data Link Layer	Data Frames: MAC address, packet (physical addressing, Media Access Control, LLC, frame error checking, sequencing and reordering)	PPP/SLIP	Frames
1. Physical Layer	Physical Device: Cables, fibers, RF spectrum (data encoding, media attachment, baseband/broadband, signaling, binary transmission)	Coax, fiber, wireless	Bits / Signals



6LoWPAN Protocol Stack	Simplified OSI Model
HTTP, CoAP, MQTT, Etc.	5. Application Layer
UDP, TCP Security: TLS/DTLS	4. Transport Layer
IPV6, RPL	3. Network Layer
6LoWPAN	2. Data Link Layer
IEEE 802.15.4 MAC Layer	1. Physical Layer
IEEE 802.15.4 PHY	



IPv6 Header

4 bits 8 bits 20 bits 16 bits 8 bits 8 bits 64 bit prefix, 64 bit HD 64 bit prefix, 64 bit HD

Version	Traffic Class	Flow Label	Flow Label	Next Header	Hop Limit	Source Address	Destination Address
---------	---------------	------------	------------	-------------	-----------	----------------	---------------------

1. Within 6LoWPAN mesh

FF80::00FF:1234:4321:0001 → FF80::00FF:1234:4321:0002

8 bits 8 bits

Dispatch	Comp. Header
----------	--------------

2. Communication from 6LoWPAN device to known address outside mesh

1003::9876:ABCD:0000:0001 → 1003::1234:4321:AAAA:BBBB

8 bits 8 bits 8 bits 8 bits 64 bit HD

Dispatch	Comp. Header	CID	Hop Limit	Destination Address
----------	--------------	-----	-----------	---------------------

3. Communication from 6LoWPAN device to external device without known prefix

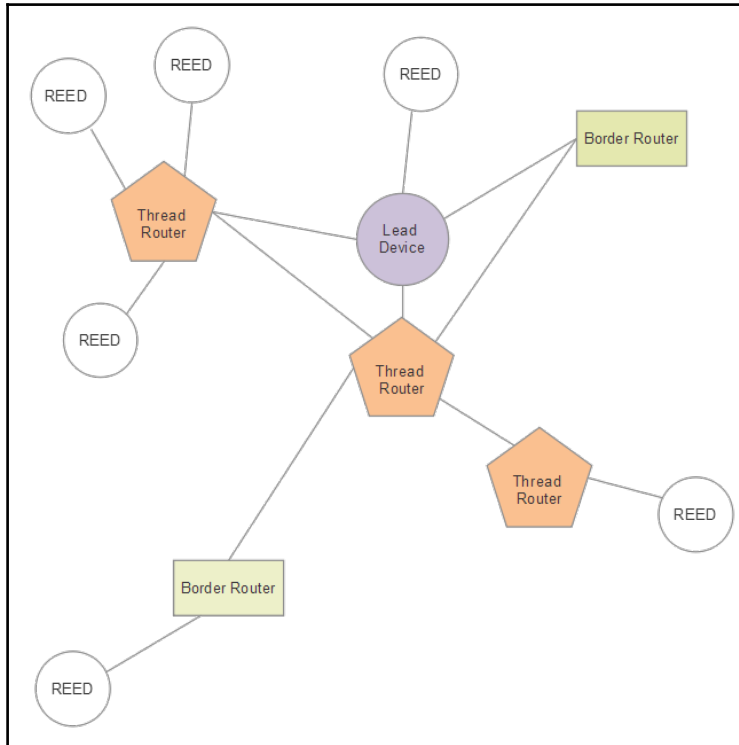
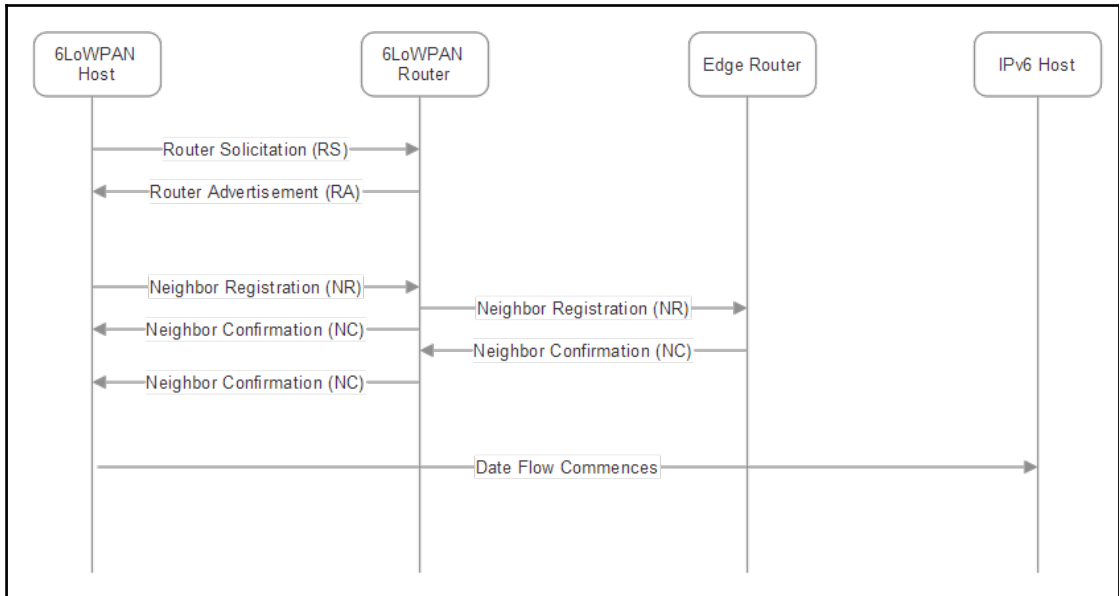
1003::9876:ABCD:0000:0001 → 1003::1234:4321:AAAA:BBBB

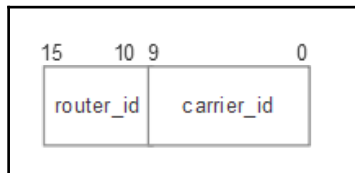
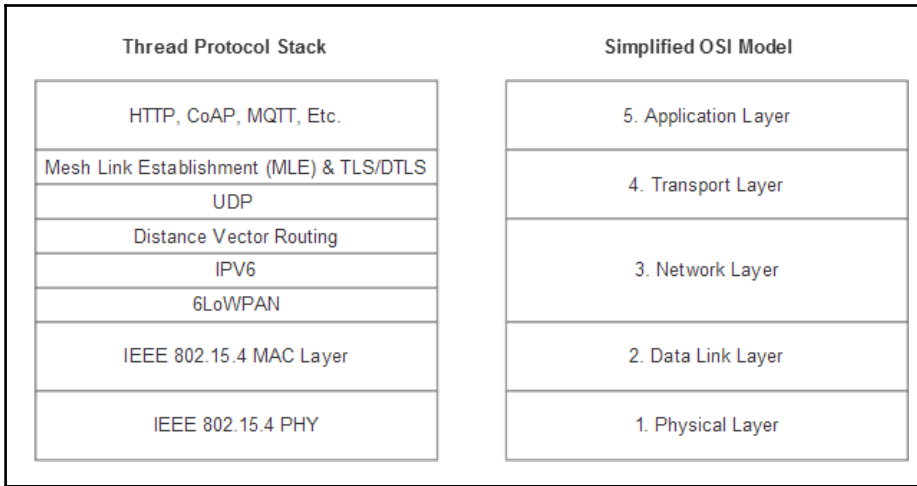
8 bits 8 bits 8 bits 8 bits 64 bit prefix 64 bit prefix, 64 bit HD

Dispatch	Comp. Header	CID	Hop Limit	Source Address	Destination Address
----------	--------------	-----	-----------	----------------	---------------------

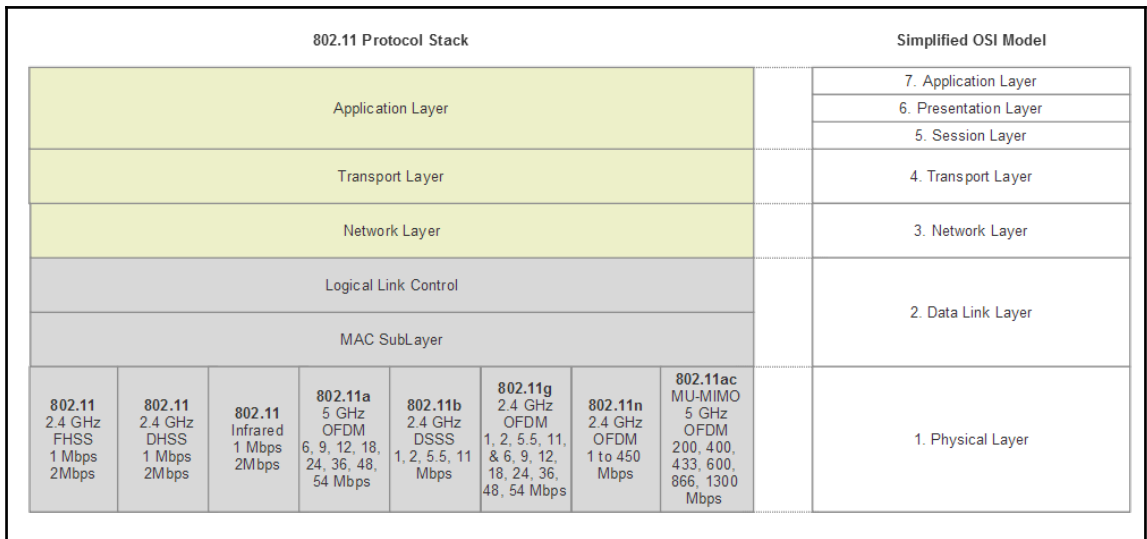
6LoWPAN Fragmentation Header

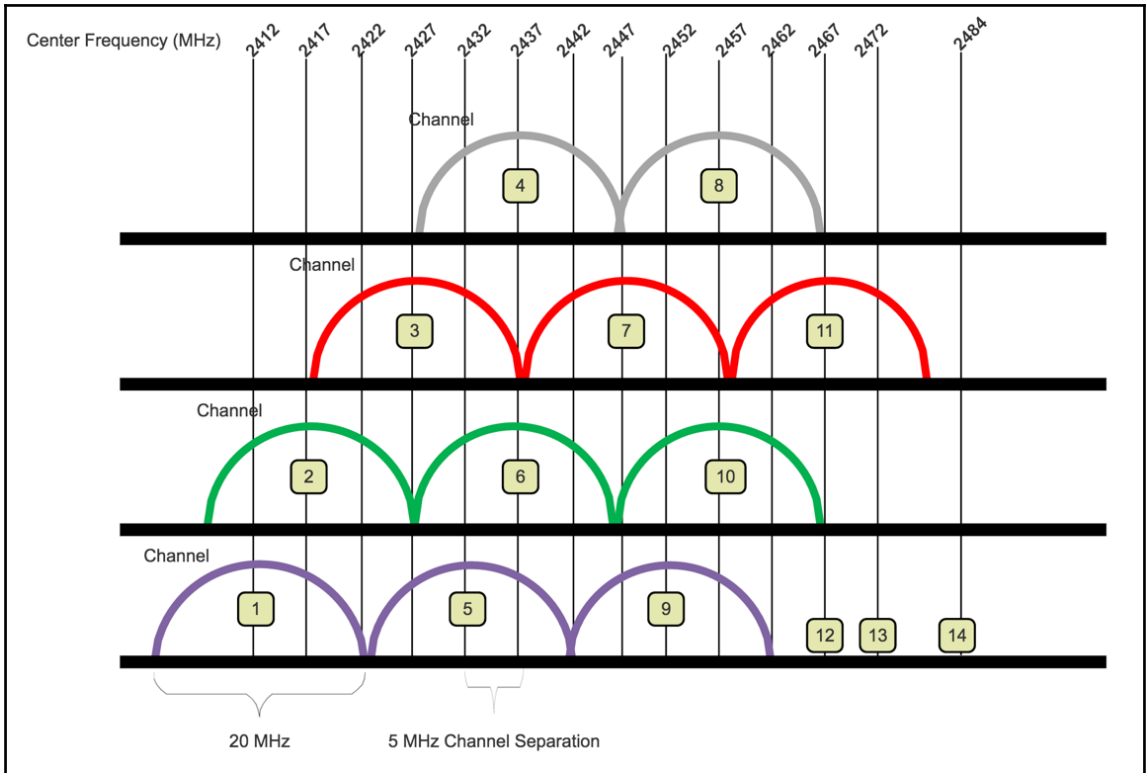
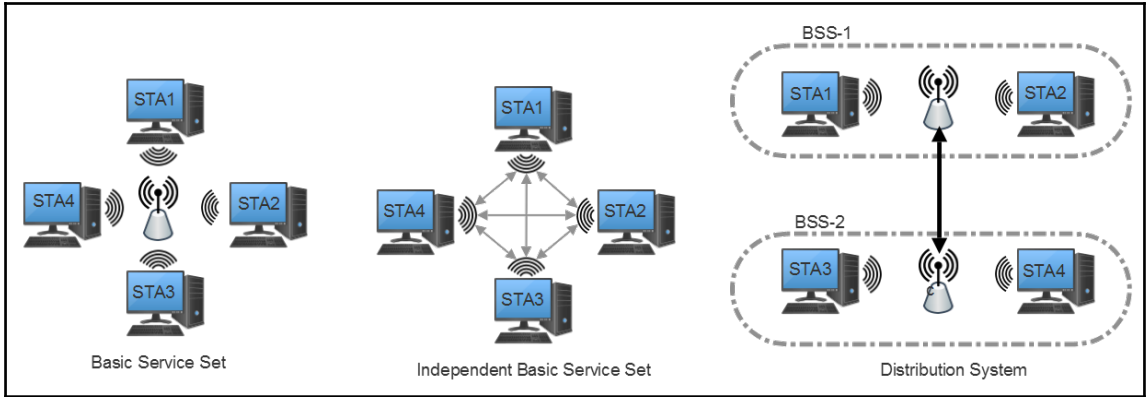
802.15.4 Header		8 bits	8 bits	16 bits	
802.15.4 Header		6LoWPAN Fragmentation Header	Datagram Size	Datagram Tag	Datagram Offset
					FCS

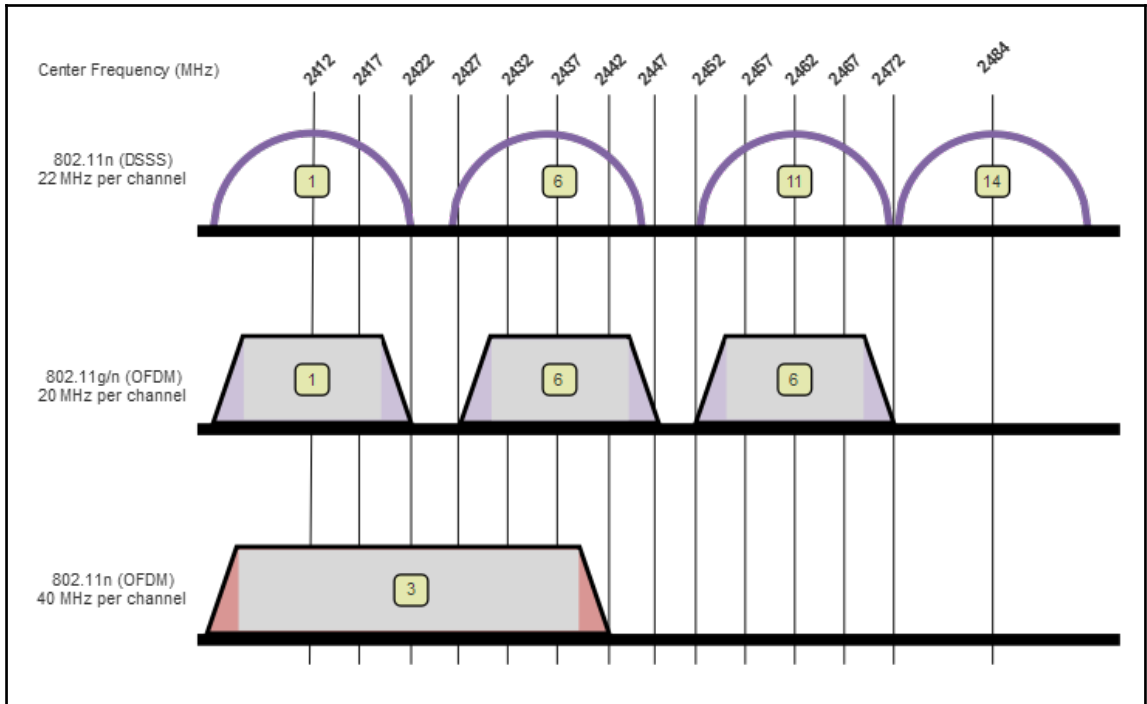


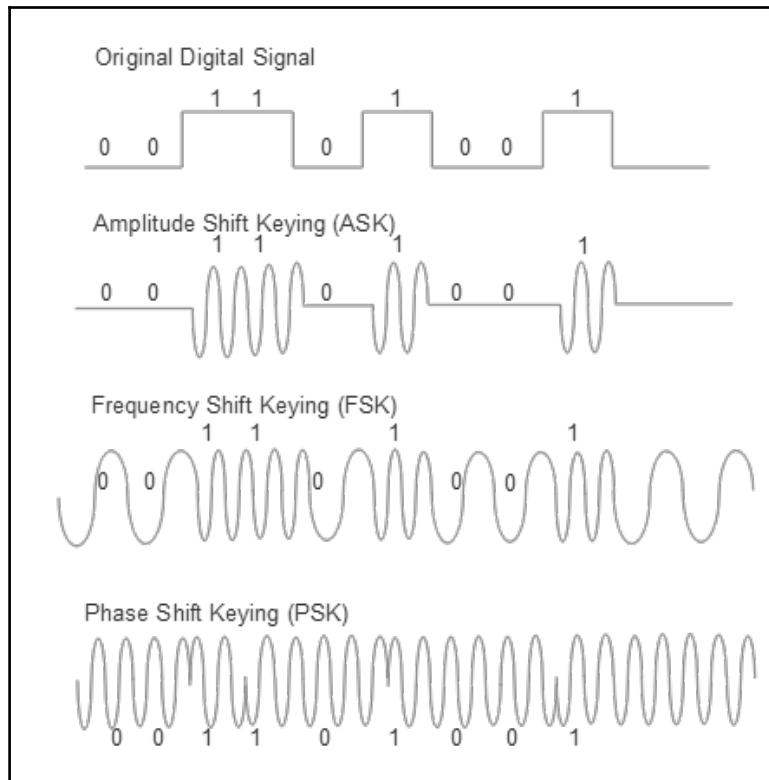


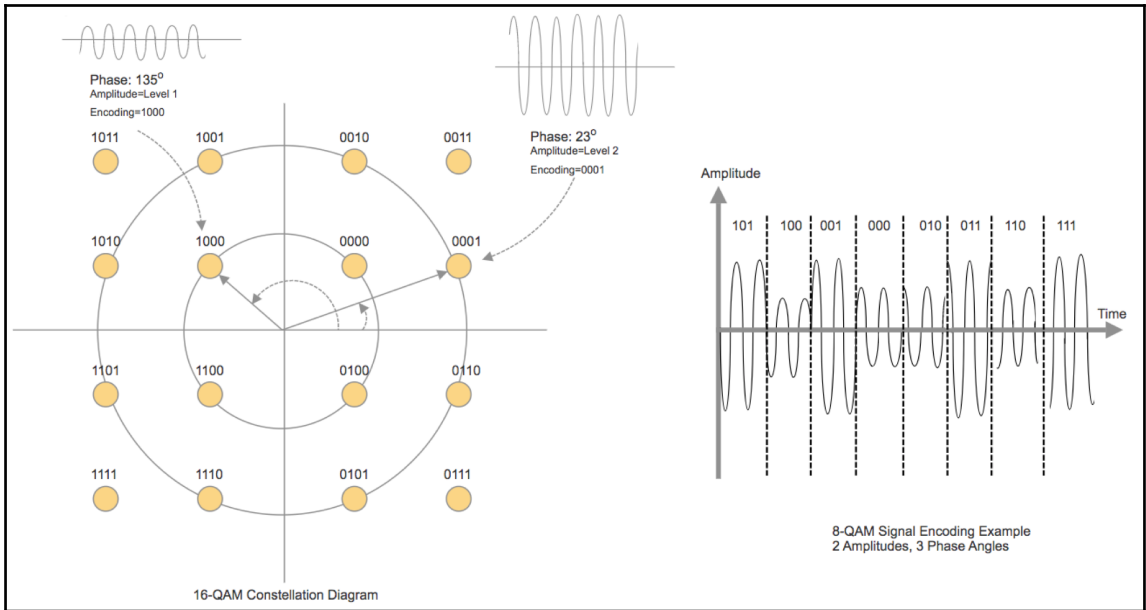
IEEE 802.11 Protocol	Use Case	Release Date	Frequency (GHz)	Bandwidth (MHz)	Streaming Data Rate per Channel min-max (Mbps)	Allowable MIMO Streams	Modulation	Indoor Range (m)	Outdoor Range (m)	Typical Dissipated Power per Chip (mW)
802.11	First 802.11 design	Jun-97	2.4	22	1 to 2	1	DSSS, FHSS	20	20	50
a	Release simultaneously with 802.11b Less prone to interference than 802.11b	Sep-99	5	20	6 to 54	1	OFDM	30	120	50
			3.7				(SISO)		5000	
b	Release simultaneously with 802.11a Significant speed increase over 802.11a at improved range	Sep-99	2.4	22	1 to 11	1	DSSS (SISO)	50	150	7 to 50
g	Speed increase over 802.11b	Jun-03	2.4	20	6 to 54	1	OFDM, DSSS (SISO)	38	140	50
n	Multiple antenna technology for improved speed, and range.	Oct-09	2.4 / 5	20	7.2 to 72.2	4	OFDM (MIMO)	70	250	40
				40	15 to 150					
ac	Better performance and coverage over 802.11n. Wider channel and improved modulation. Allows multiple users using MU-MIMO. Introduced beamforming.	Dec-13	5	20	7.2 to 96.3	8	OFDM (MU-MIMO)	35	35	40
				40	15 to 200					
				80	32.5 to 433.3					
				160	65 to 866.7					
ah	"WiFi HaLow" Designed for IoT and sensor networks. Very low power and wider range.	Dec-16	2.4 / 5	1 to 16	347	4	OFDM	1000	1000	tbd but goal is low power
p	"Wireless Access in Vehicular Environments" "Intelligent Transport Systems" Dedicated Short Range Communication Transport uses cases: toll collection, safety and collision emergencies, vehicular networking.	Jun-09	5.9	10	27	1	OFDM	NA	400 to 1000	40
af	"white WiFi" or "Super WiFi" Deploy unused spectrum in TV bands to provide last mile connectivity in India, Kenya, Singapore, US and UK	Nov-13	0.470 to 0.710	6 to 8	568	4	OFDM	NA	6000-100,000	tbd
ad	WiGig Alliance 60 GHz Wireless for HD video and projectors Audio and video transport and cable replacement	Dec-12	60	2160	4260	>10	SC, OFDM (MU-MIMO)	10	10	tbd
ax	"High Efficiency Wireless (HEW)" Next gen 802.11 4x increase in capacity over 802.11ac Average increase of 4x speed per user over 802.11ac Backwards compatible to 802.11a/b/g/n/ac Dense deployment scenarios	2019	2.4 / 5	20	450 to 10000	8	OFDMA (MU-MIMO)	35	35	tbd
				40						
				80						
				160						

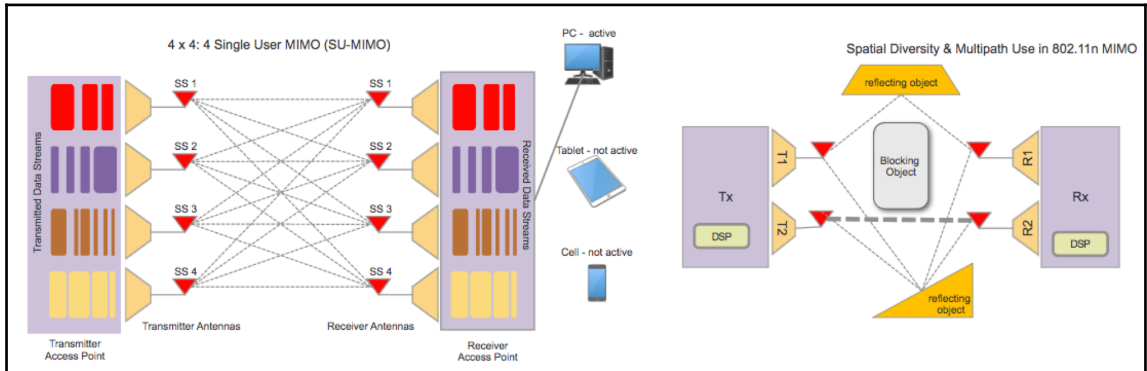
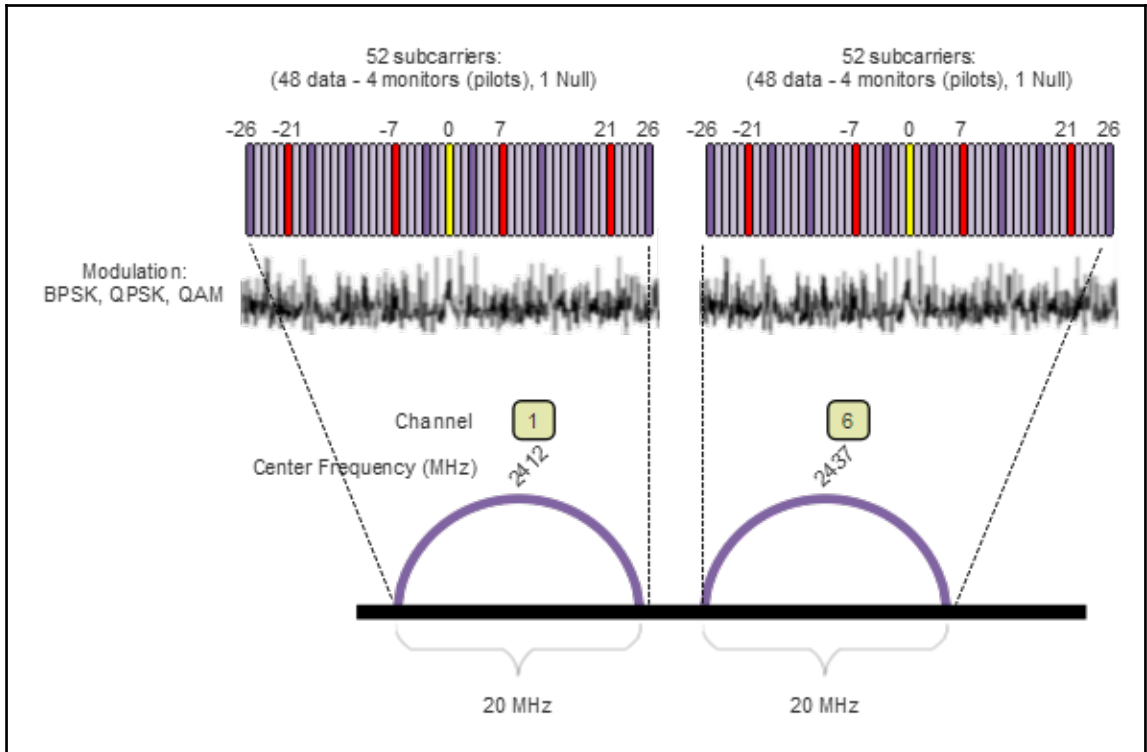


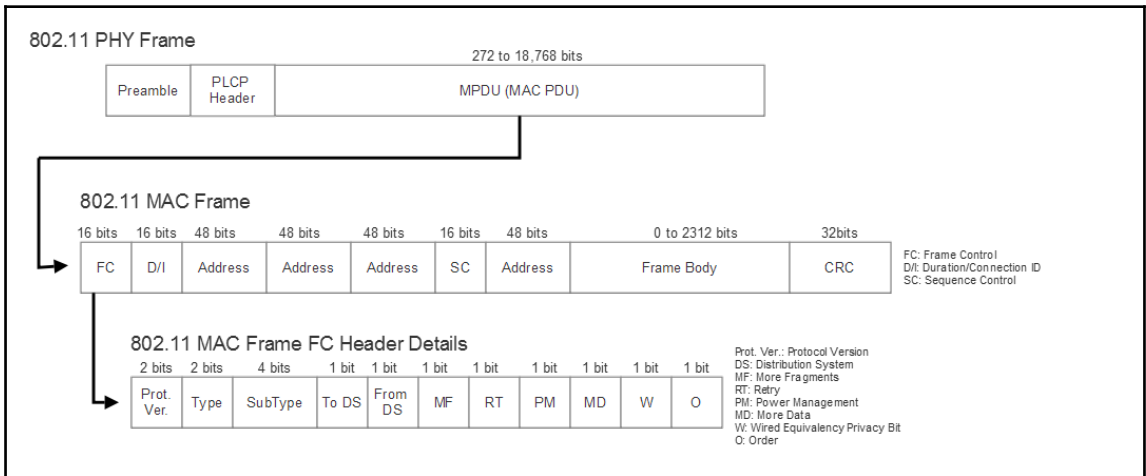
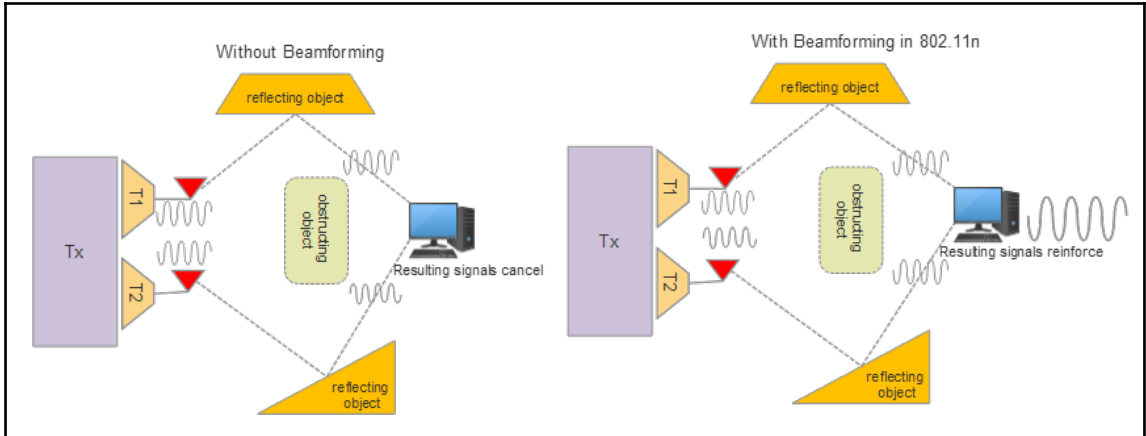


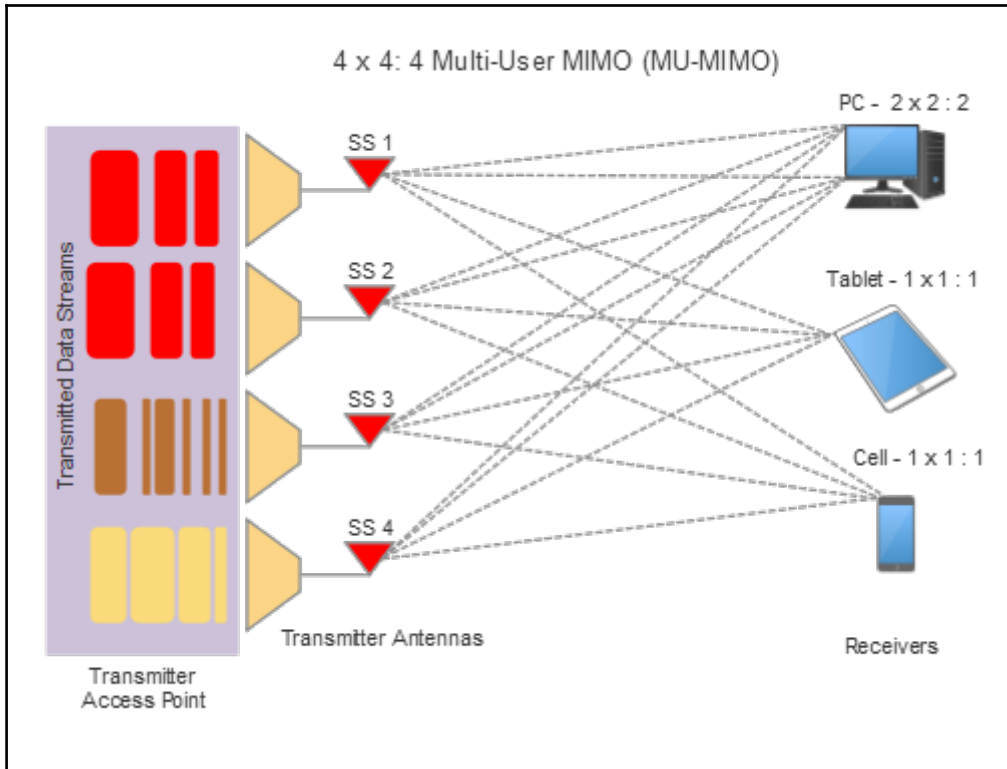


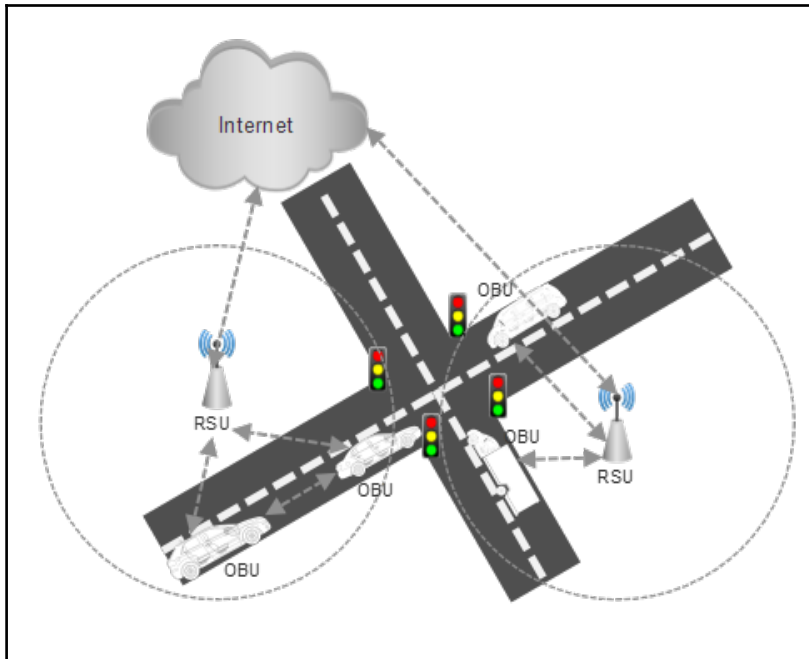




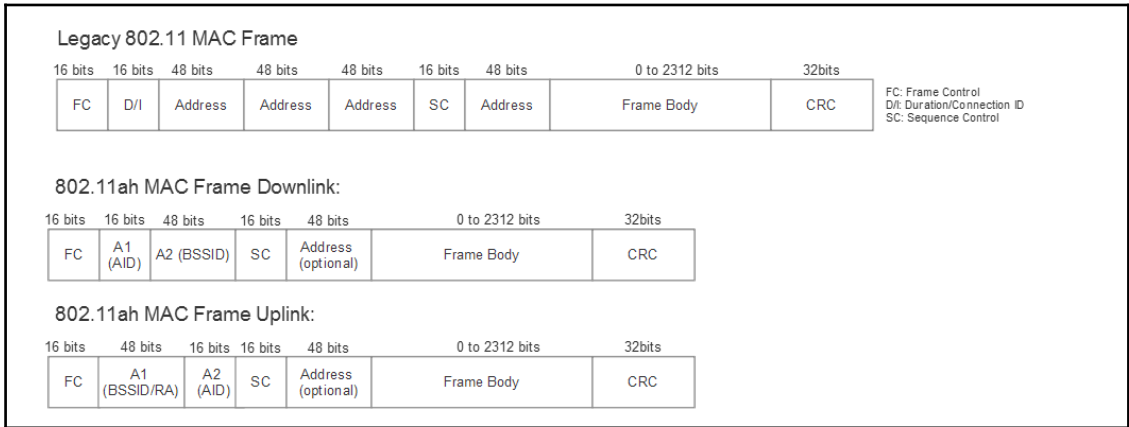
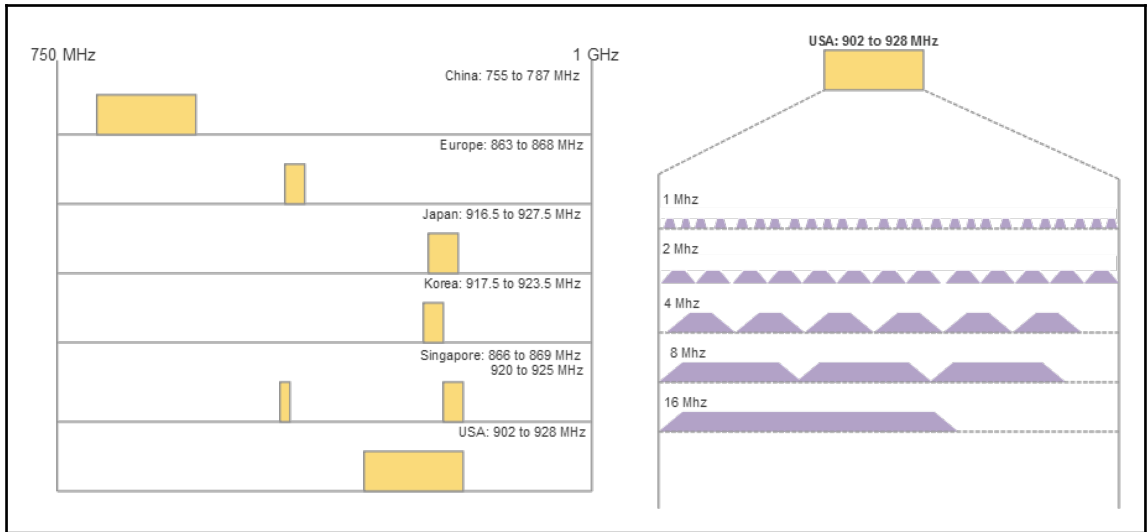


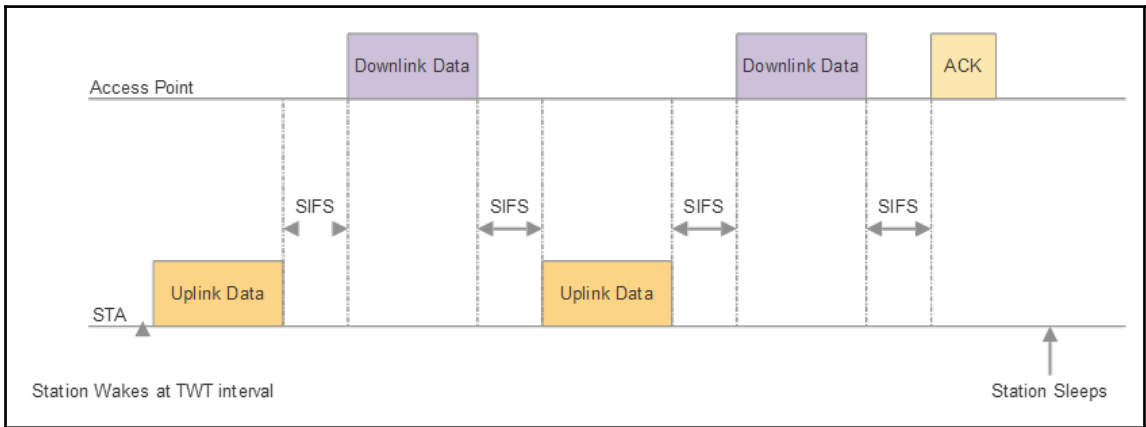
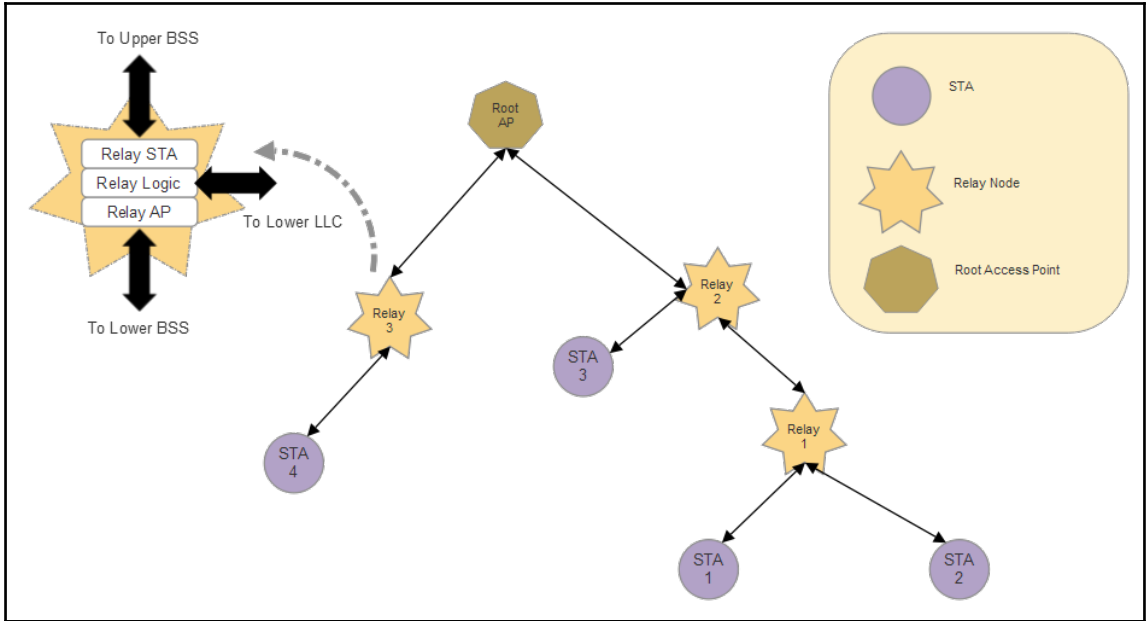




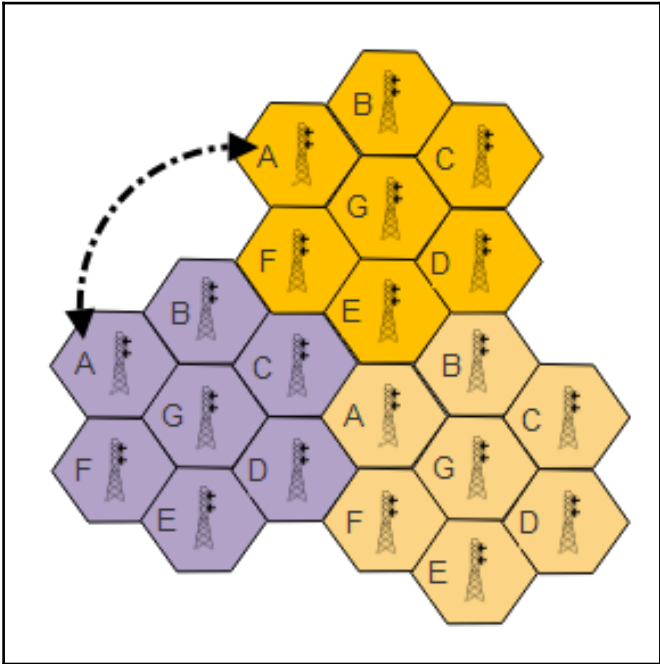


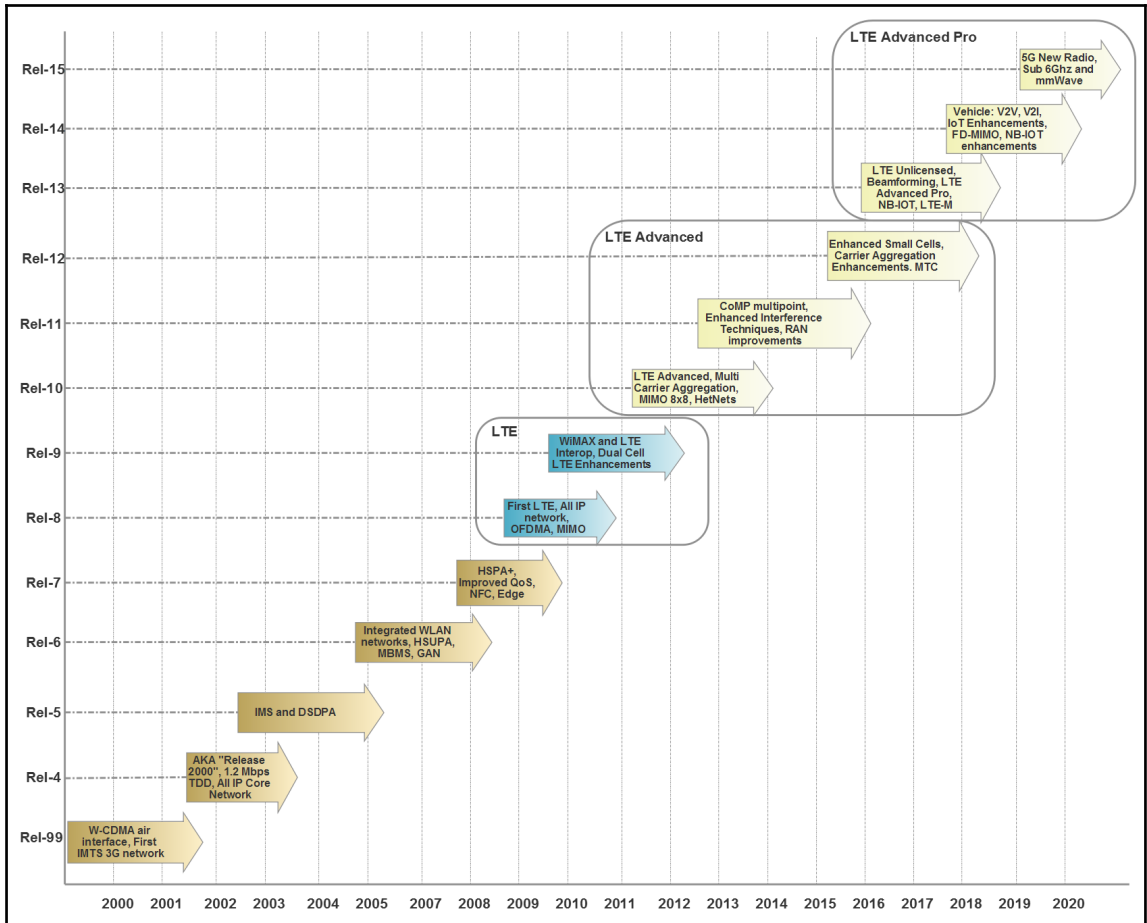
802.11 Protocol Stack		Simplified OSI Model
IEEE 1609.1 (Safety and Traffic Efficiency Applications)		7. Application Layer
IEEE 1609.2 WAVE Security Services		4. Transport Layer
TCP/UDP	IEEE 1609.3 VWSMP	
IPV6		3. Network Layer
Logical Link Control		2. Data Link Layer
IEEE 1609.4 MAC SubLayer		
802.11p 5 GHz OFDM 3, 4.5, 6, 9, 12, 18, 24, 27 Mbps		1. Physical Layer

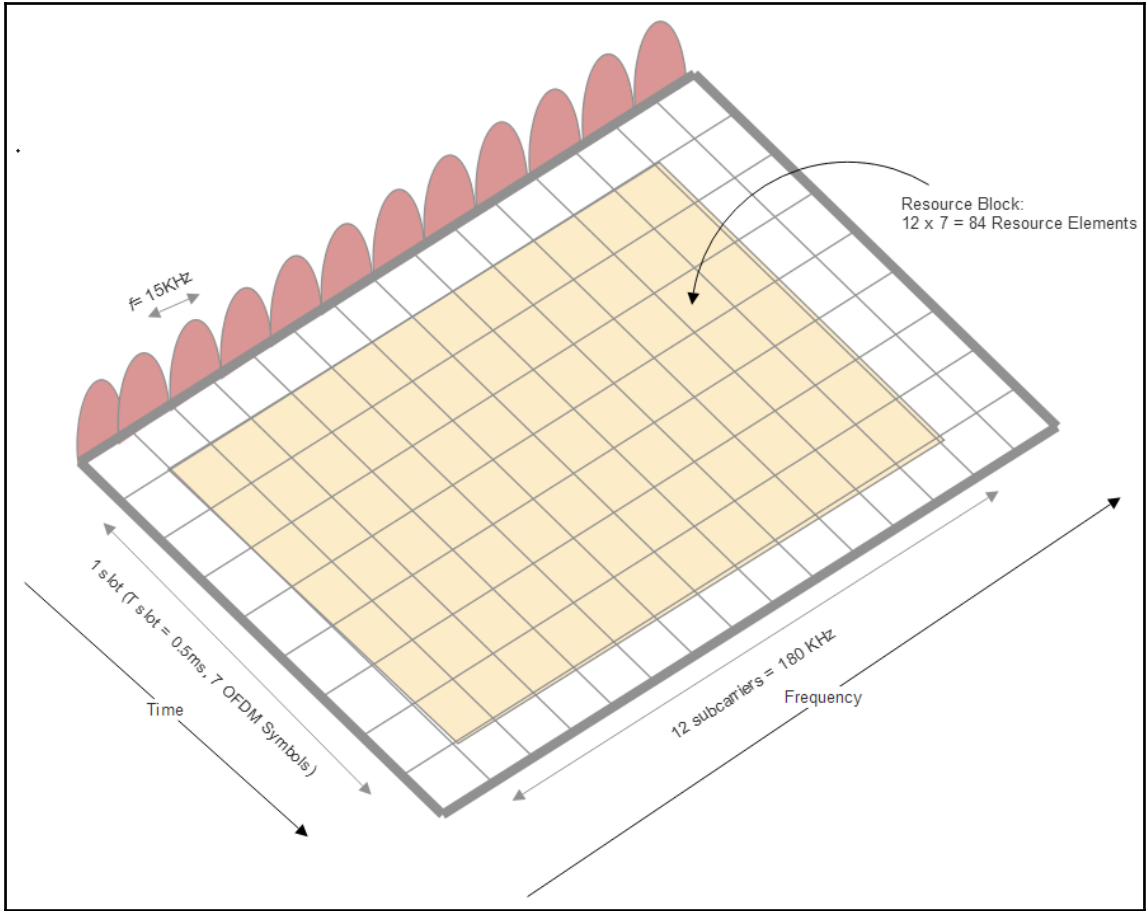




Chapter 7: Long-Range Communication Systems and Protocols (WAN)

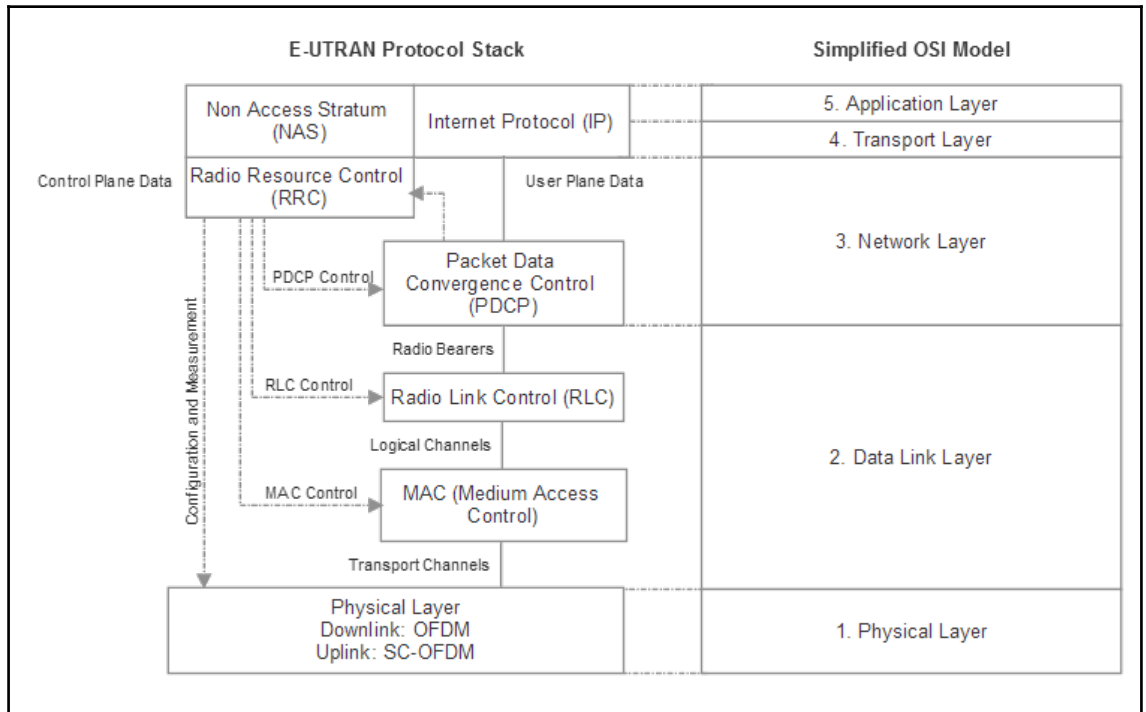
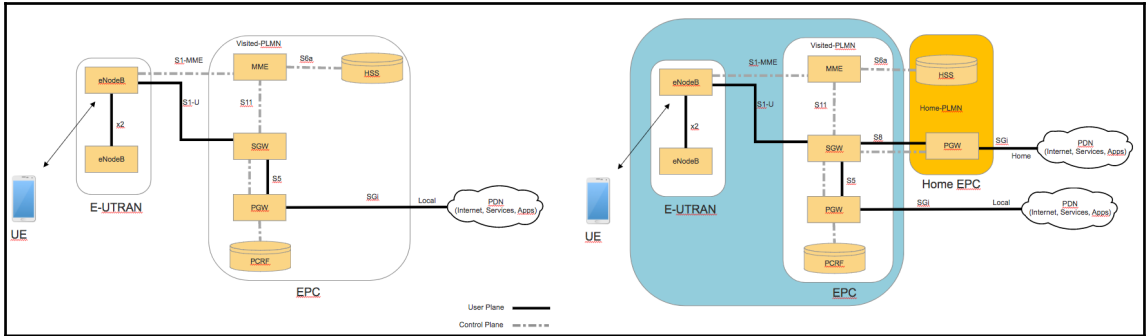


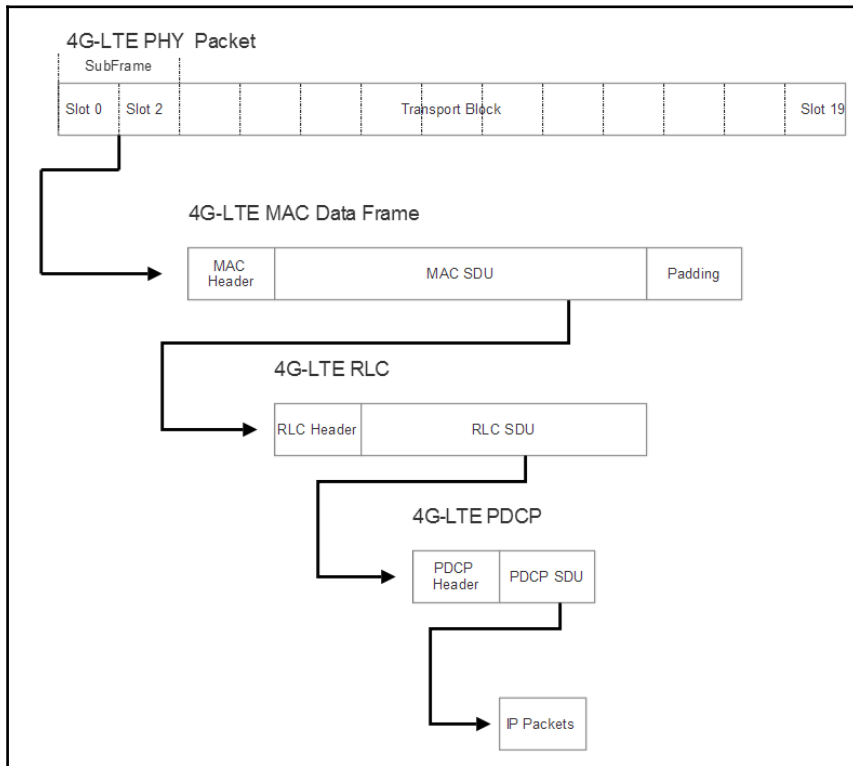
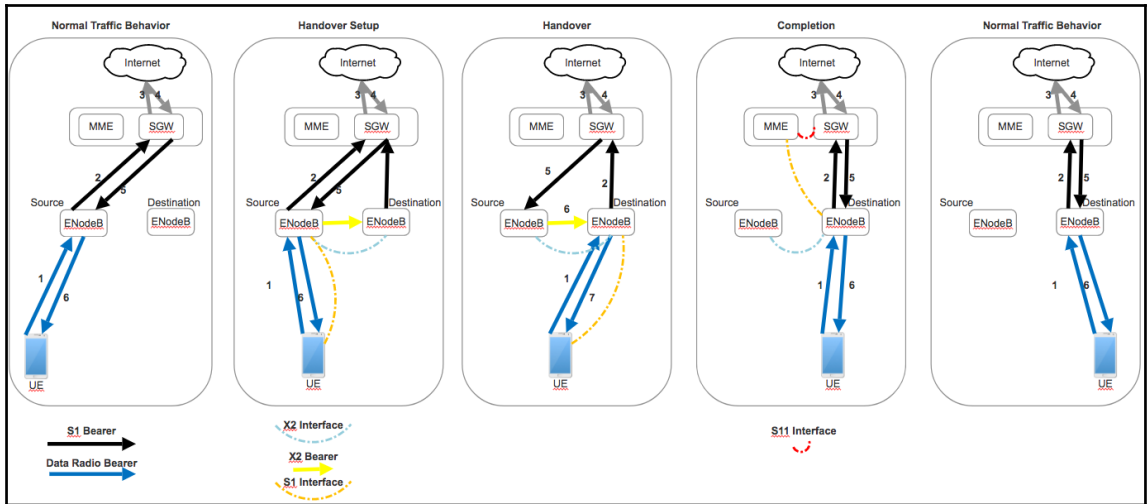


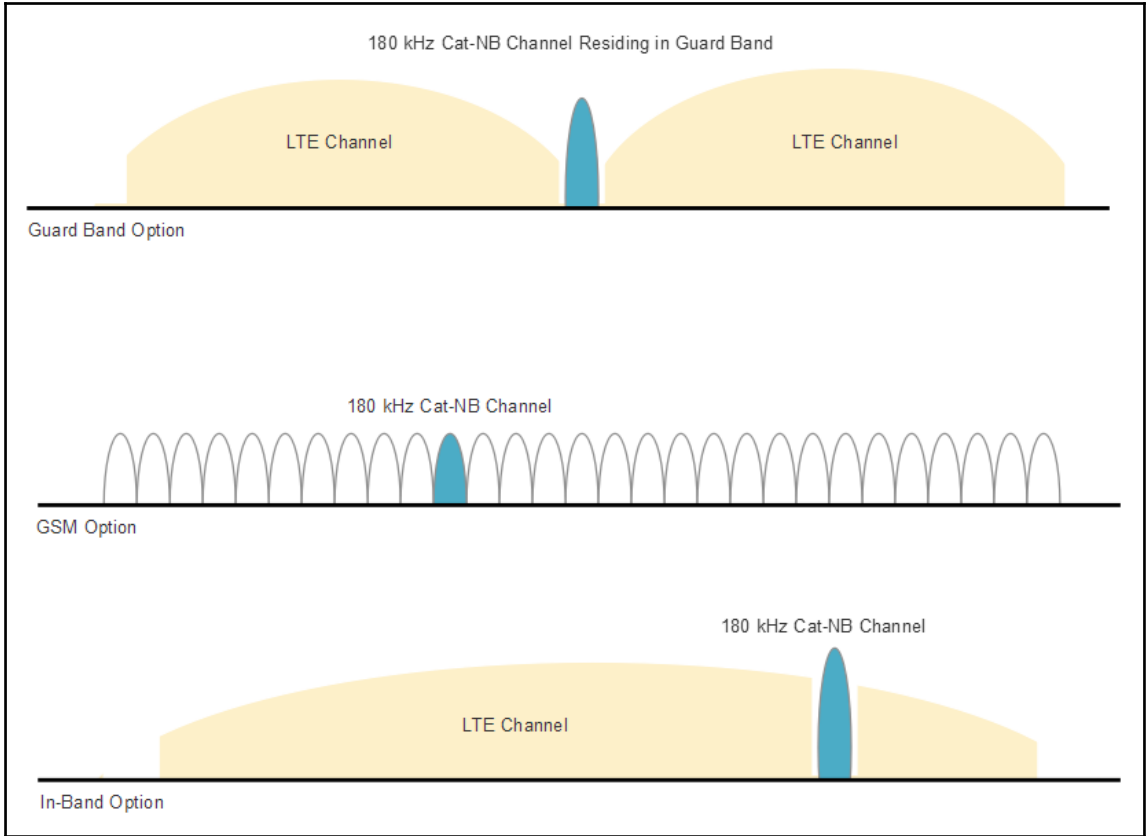


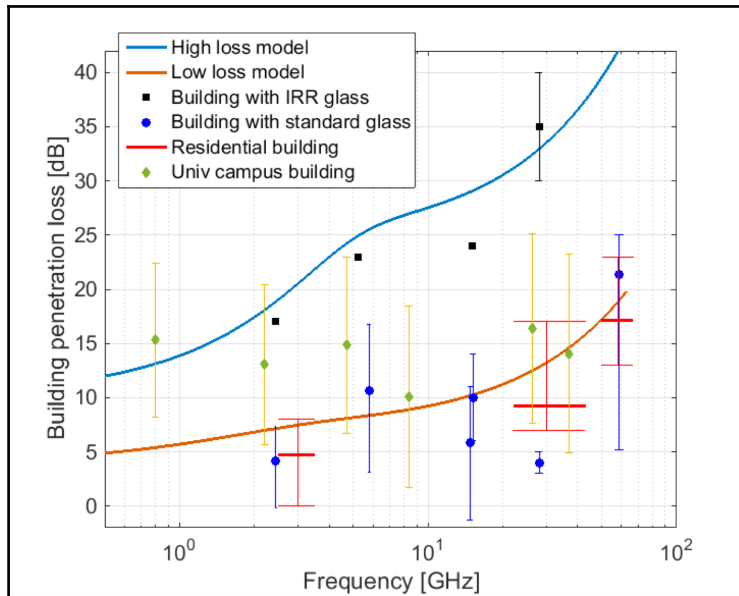
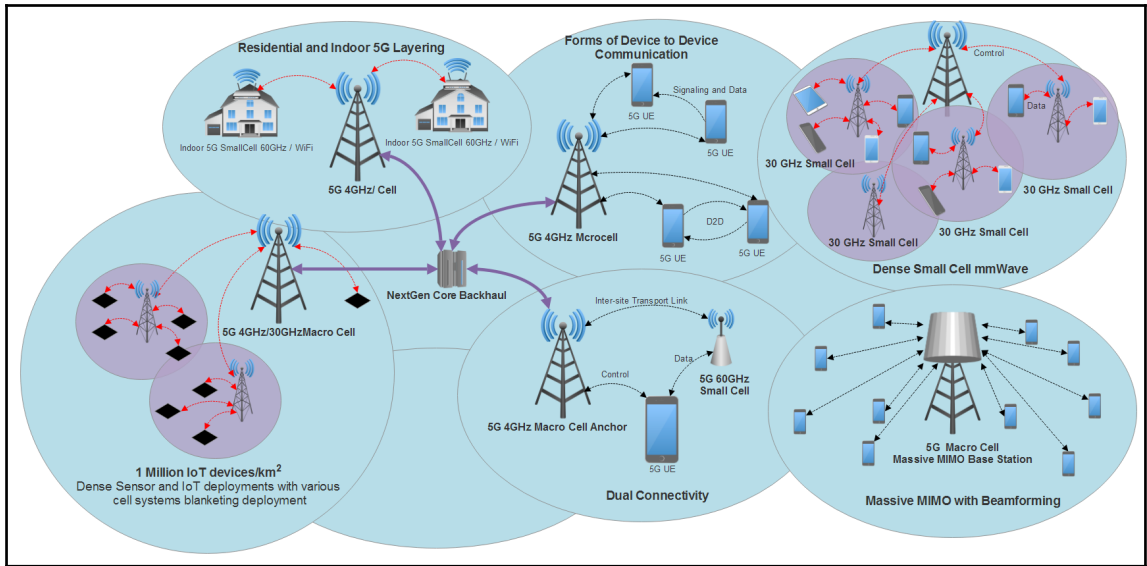
Band	Duplex	f (MHz)	Common Name	North America	Width of Band (MHz)	Duplex Space (MHz)	Band Gap (MHz)
1	FDD	2100	IMT		60	190	130
2	FDD	1900	PCS blocks A-F	Yes	60	80	20
3	FDD	1800	DCS		75	95	20
4	FDD	1700	AWS blocks A-F (AWS-1)	Yes	45	400	355
5	FDD	850	CLR	USA (AT&T, U.S. Cellular)	25	45	20
6	FDD				10	35	25
7	FDD	2600	IMT-E	Canada (Bell, Rogers, Telus)	70	120	50
8	FDD	900	E-GSM		35	45	10
9	FDD				35	95	60
10	FDD	1700	Extended AWS blocks A-I		60	400	340
11	FDD	1500	Lower PDC	Canada (Bell), Guam (iConnect, ...)	20	48	28
12	FDD	700	Lower SMH blocks A/B/C	USA (Verizon), Canada (Bell, EastLink, ...)	18	30	12
13	FDD	700	Upper SMH block C	USA (FirstNet)	10	-31	41
14	FDD	700	Upper SMH block D		10	-30	40
15	FDD	2000			20	700	680
16	FDD	700			15	575	560
17	FDD	700	Lower SMH blocks B/C	Canada (Rogers), Guam (NTT), USA (AT&T)	12	30	18
18	FDD	850	Japan lower 800		15	45	30
19	FDD	850	Japan upper 800		15	45	30
20	FDD	800	EU Digital Dividend		30	-41	71
21	FDD	1500	Upper PDC		15	48	33
22	FDD	3500		USA (Ligado Networks)	90	100	10
23	FDD	2000			20	180	160
24	FDD	1600	L-Band (US)		34	-101.5	135.5
25	FDD	1900	Extended PCS blocks A-G	USA (Sprint)	65	80	15
26	FDD	850	Extended CLR	USA (Sprint)	30 / 40		10
27	FDD	800	SMR		17	45	28
28	FDD	700	APT		45	55	10
29	FDD[A 1]	700	Lower SMH blocks D/E	USA (AT&T)	11	n/a	
30	FDD	2300	WCS blocks A/B	USA (AT&T)	10	45	35
31	FDD	450			5	10	5
32	FDD[A 1]	1500	L-Band (EU)		44	n/a	
65	FDD	2100	Extended IMT		90	190	
66	FDD	1700	Extended AWS blocks A-J	Canada (Freedom Mobile)	90/70	400	
67	FDD[A 1]	700	EU 700		20	n/a	
68	FDD	700	ME 700		30	55	
69	FDD[A 1]	2600	IMT-E (Duplex spacing)		50	n/a	
70	FDD	2000	AWS-4	USA (DISH)	25/15	300	
71	FDD	600	US Digital Dividend	USA (T-Mobile)			

Band	Duplex	f (MHz)	Common Name	North America	Allocation (MHz)	Width of Band (MHz)
33	TDD	2100	IMT		1900 – 1920	20
34	TDD	2100	IMT		2010 – 2025	15
35	TDD	1900	PCS (Uplink)		1850 – 1910	60
36	TDD	1900	PCS (Downlink)		1930 – 1990	60
37	TDD	1900	PCS (Duplex spacing)		1910 – 1930	20
38	TDD	2600	IMT-E (Duplex Spacing)		2570 – 2620	50
39	TDD	1900	DCS-IMT gap		1880 – 1920	40
40	TDD	2300			2300 – 2400	100
41	TDD	2500	BRS / EBS	USA (Sprint)	2496 – 2690	194
42	TDD	3500			3400 – 3600	200
43	TDD	3700			3600 – 3800	200
44	TDD	700	APT		703 – 803	100
45	TDD	1500	L-Band (China)		1447 – 1467	20
46	TDD	5200	U-NII		5150 – 5925 (unlicensed)	775
47	TDD	5900	U-NII-4 (VZXX)		5855 – 5925 (unlicensed)	70
48	TDD	3600	CBRS		3550 – 3700	150

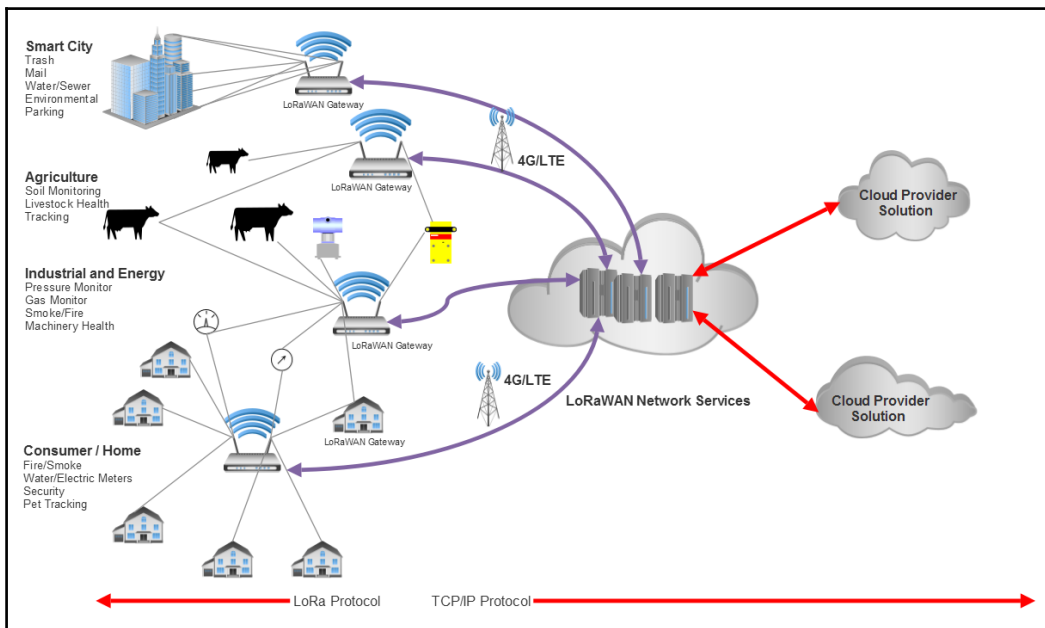
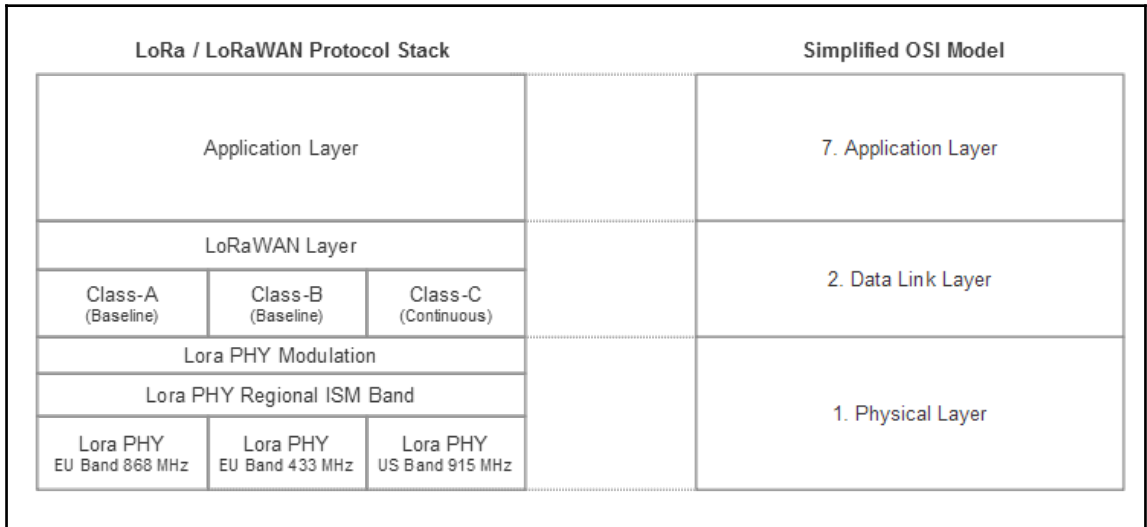


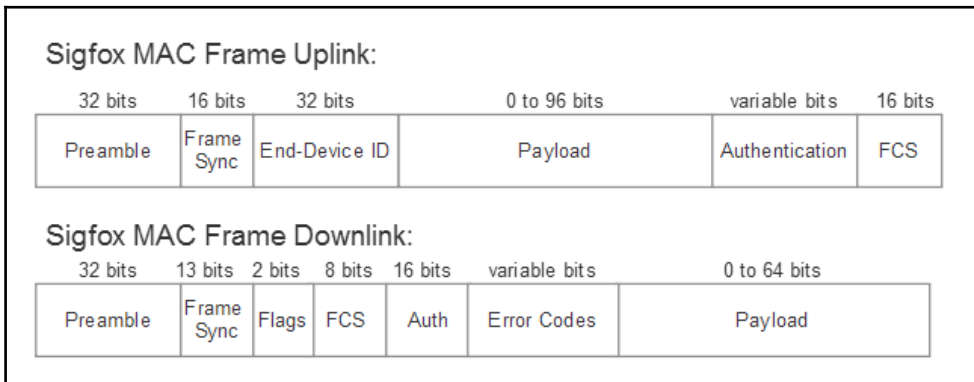
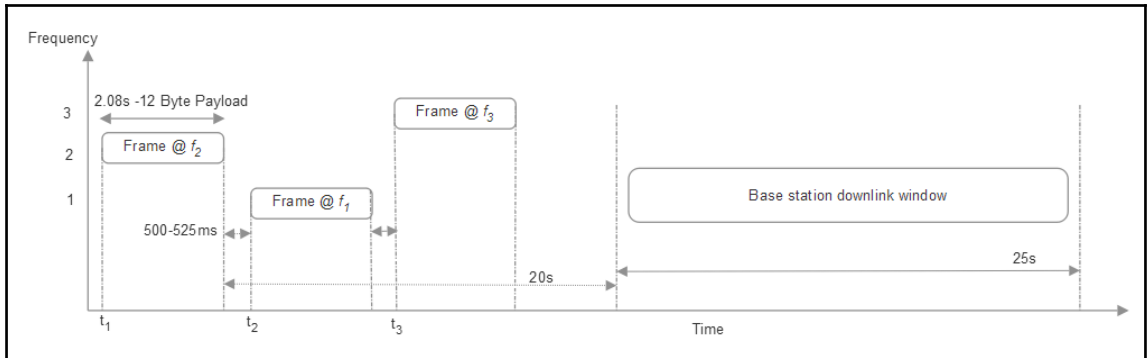






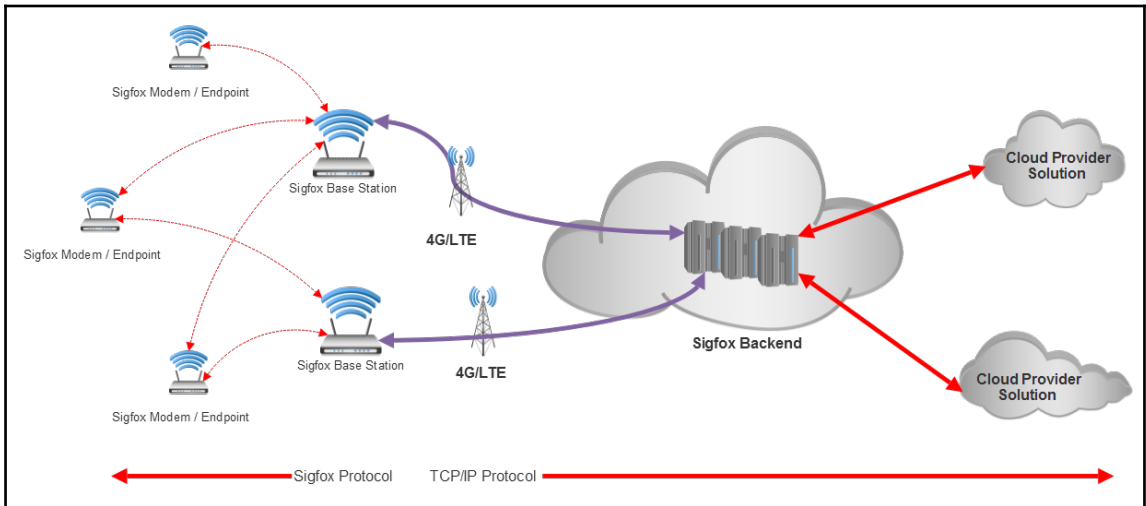
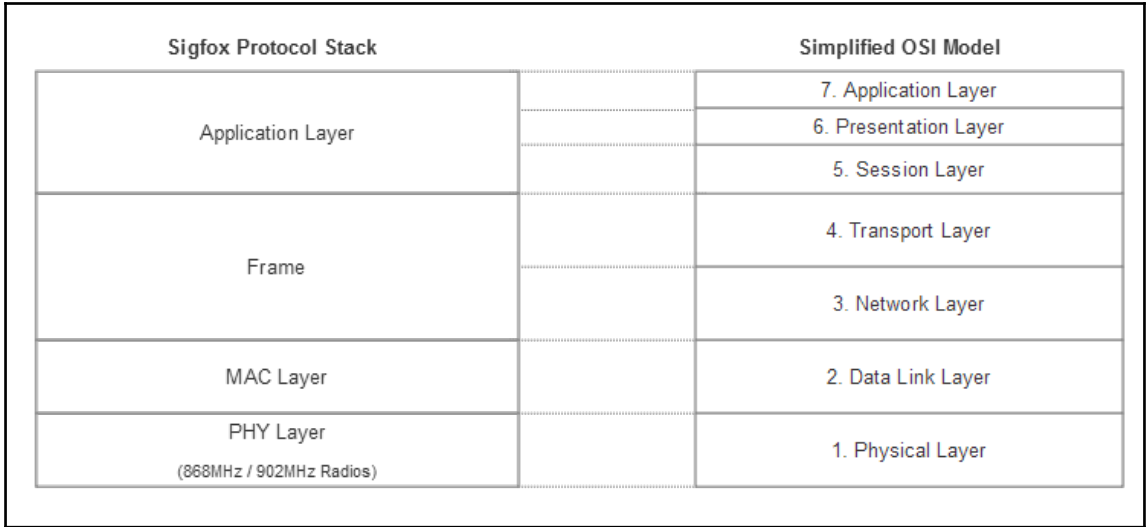
$$R_b = S \times \frac{1}{\left[\frac{2^S}{B} \right]}$$



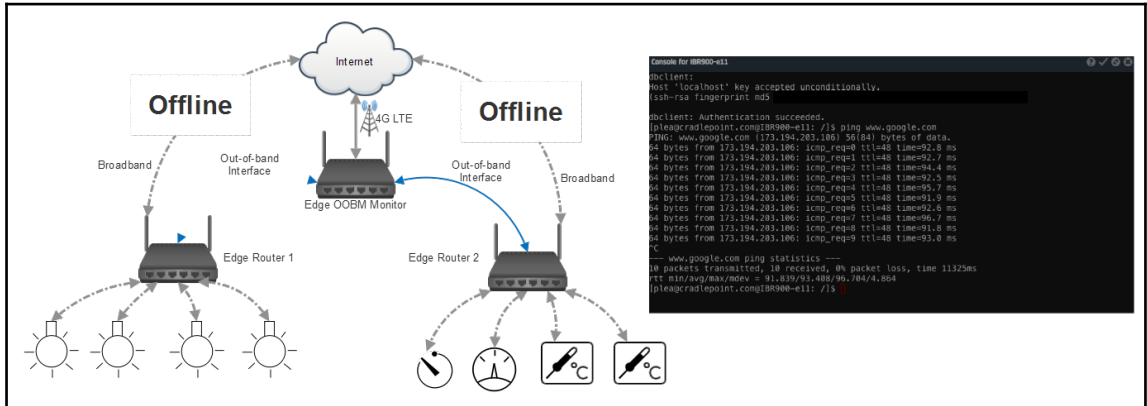


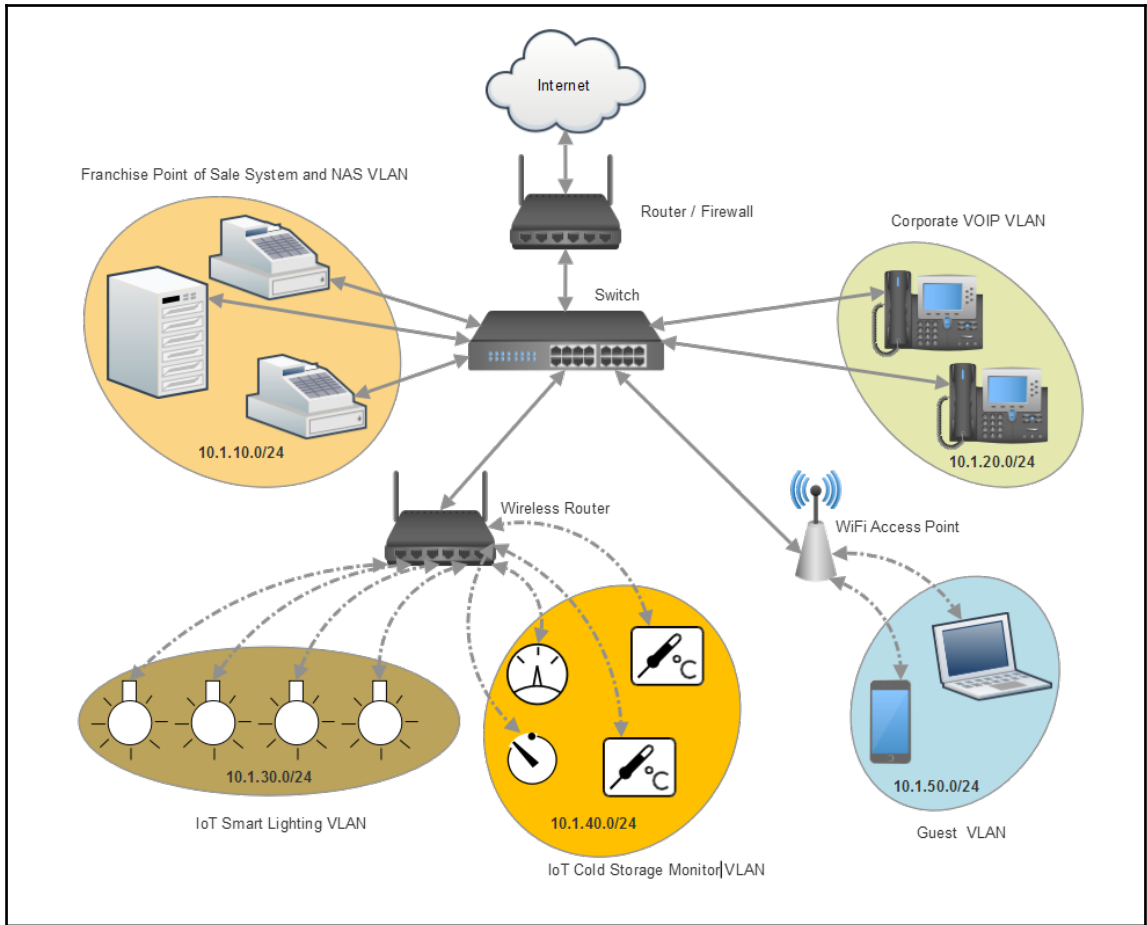
$$\frac{\sim 200 \text{ bit uplink packet}}{100\text{bps}} = 2\text{seconds}$$

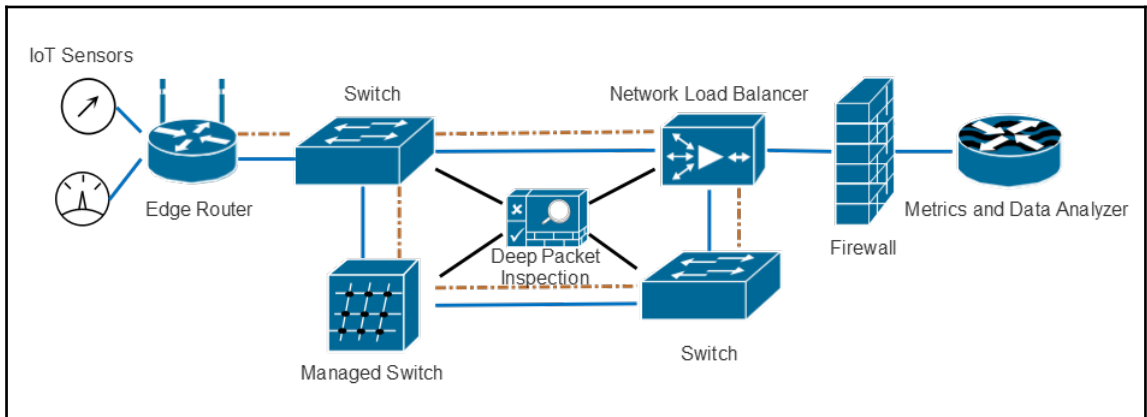
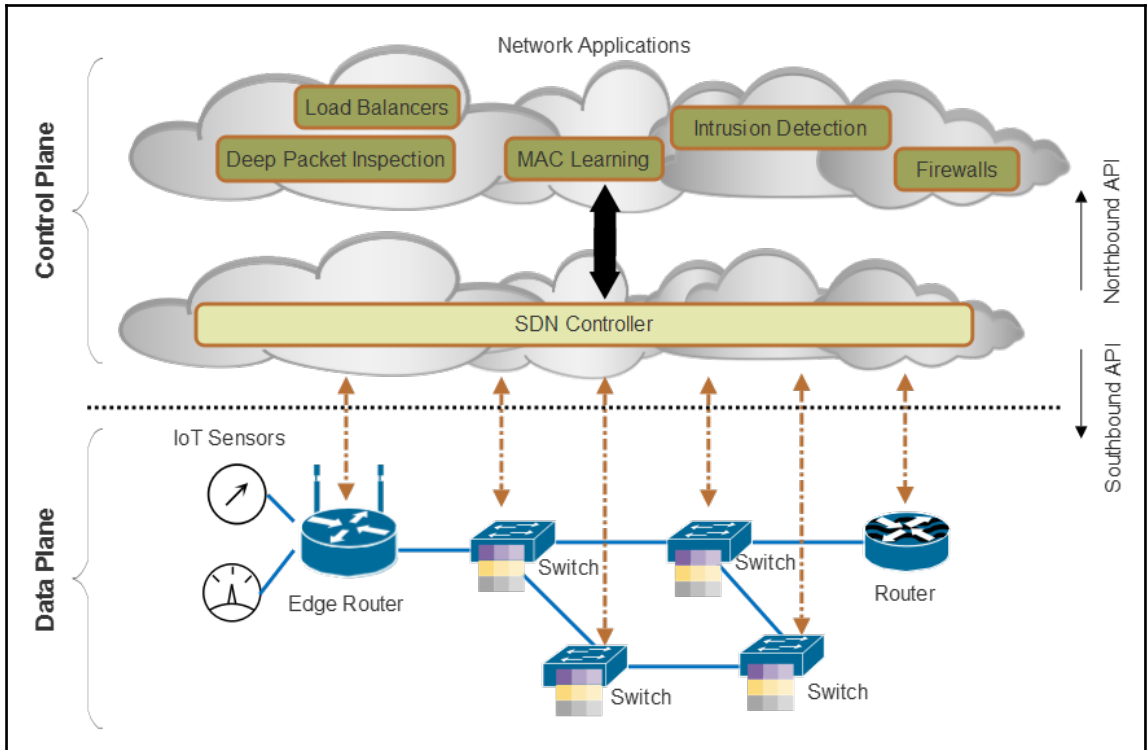
$$3600 \text{ seconds} @ 1\% \text{ duty cycle} = \frac{36 \text{ seconds message transmission time}}{\text{hour}} \times \frac{\text{message}}{3 \text{ repetitions} \times 2 \text{ seconds}} = \frac{6 \text{ messages}}{\text{hour}}$$



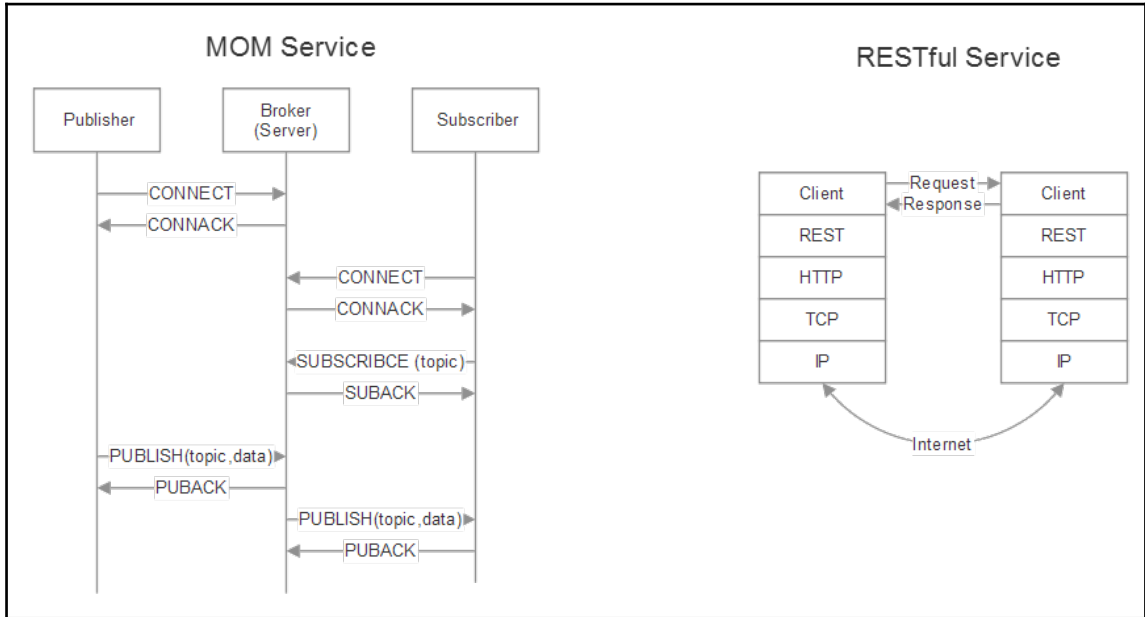
Chapter 8: Routers and Gateways

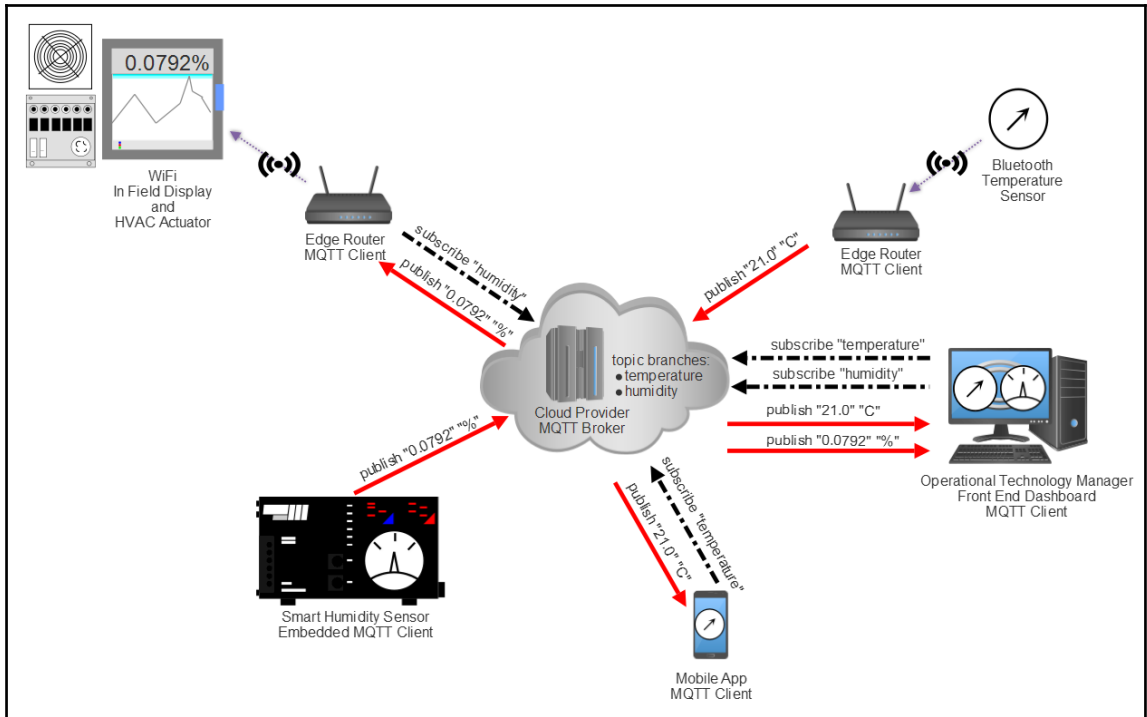






Chapter 9: IoT Edge to Cloud Protocols

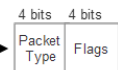




MQTT Packet Structure



MQTT Control Header

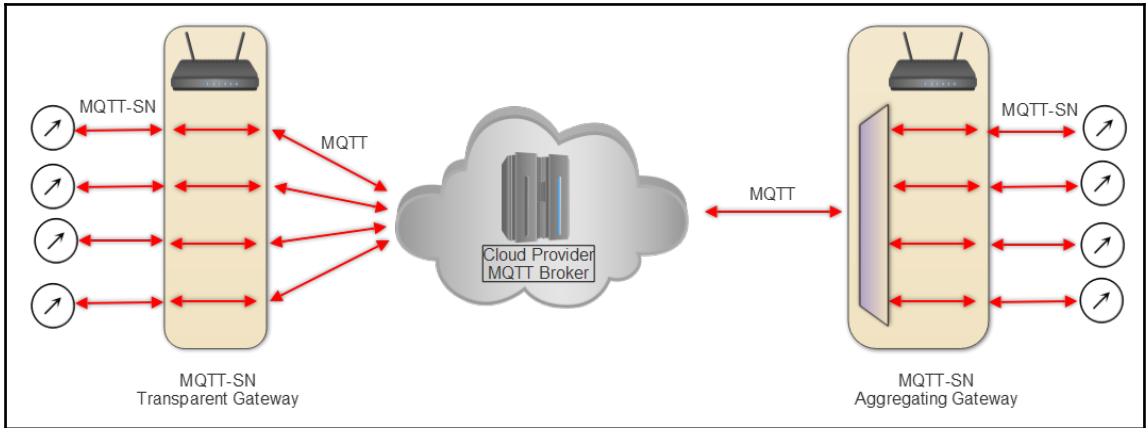
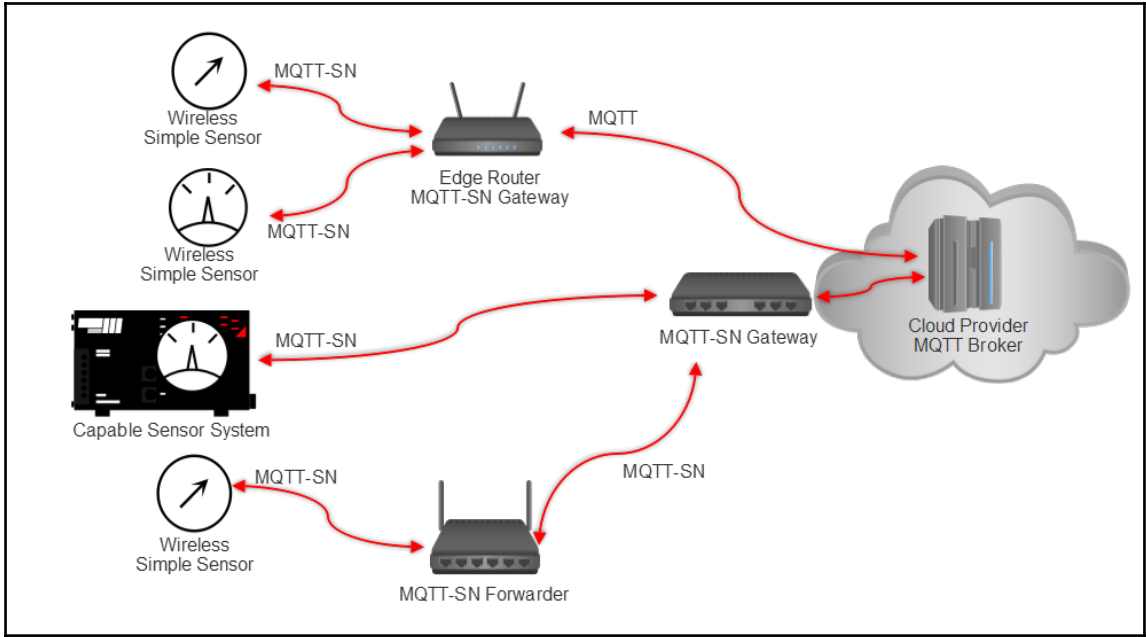


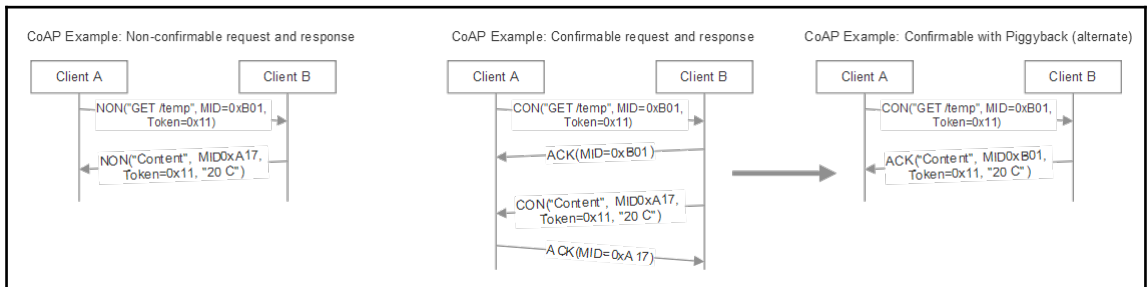
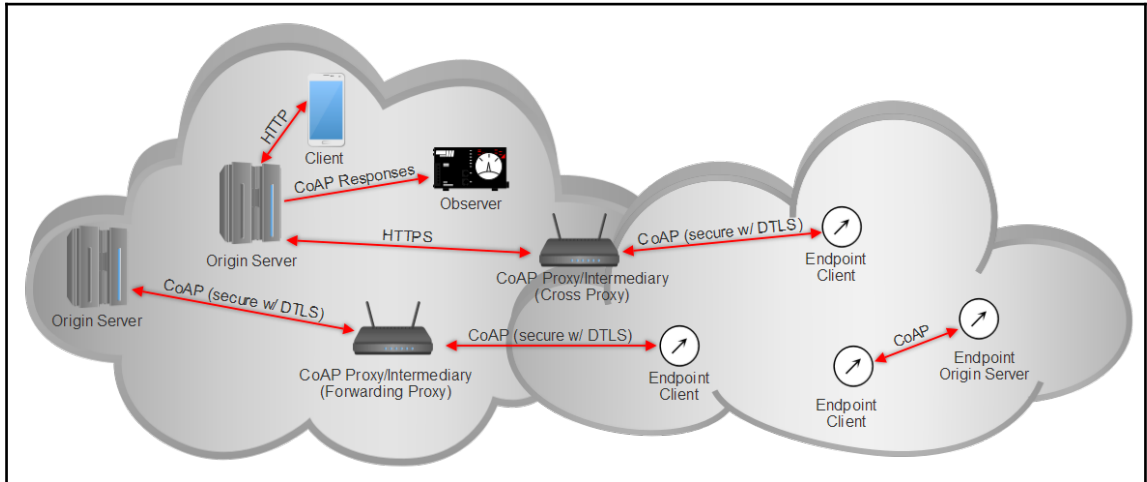
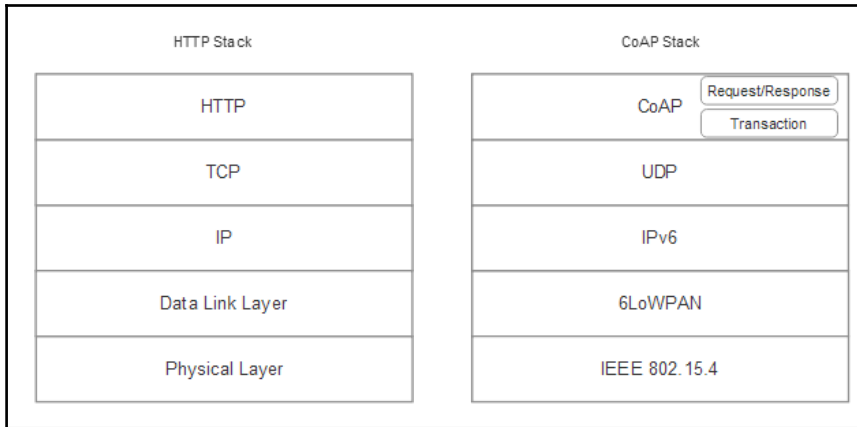
MQTT Control Packet Type

Name	Value	Direction	Description
Reserved	0	Forbidden	Reserved
CONNECT	1	Client to Server	Client connect request
CONNACK	2	Server to Client	Connect ACK
PUBLISH	3	Client to Server or Server to Client	Publish a message
PUBACK	4	Client to Server or Server to Client	Publish ACK
PUBREC	5	Client to Server or Server to Client	Publish receive (assured delivery part 1)
PUBREL	6	Client to Server or Server to Client	Publish receive (assured delivery part 2)
PUBCOMP	7	Client to Server or Server to Client	Publish complete (assured delivery part 3)
SUBSCRIBE	8	Client to Server	Client subscribe request
SUBACK	9	Server to Client	Subscribe ACK
UNSUBSCRIBE	10	Client to Server	Unsubscribe request
UNSUBACK	11	Server to Client	Unsubscribe ACK
PINGREQ	12	Client to Server	PING request
PINGRESP	13	Server to Client	PING response
DISCONNECT	14	Client to Server	Client disconnecting
Reserved	15	Forbidden	Reserved

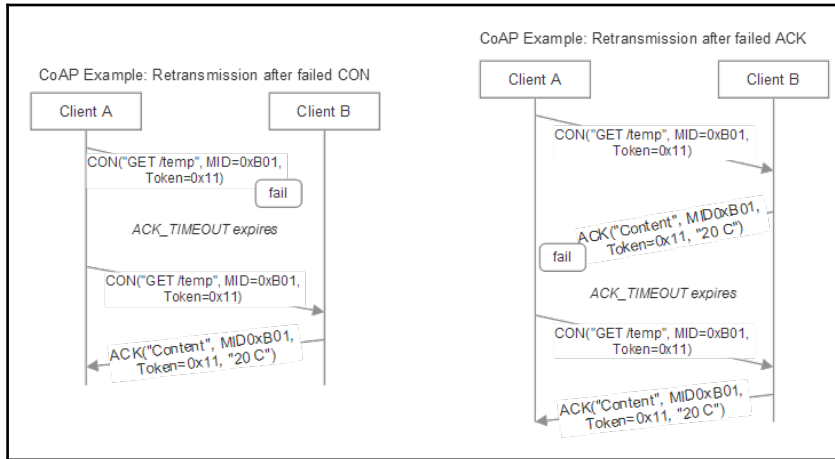
MQTT Control Packet Flags

Control Packet	Fixed Header Flags	Bit 3	Bit 2	Bit 1	Bit 0
CONNECT	Reserved	0	0	0	0
CONNACK	Reserved	0	0	0	0
PUBLISH	Used in MQTT 3.1.1	DUP	QoS	QoS	RETAIN
PUBACK	Reserved	0	0	0	0
PUBREC	Reserved	0	0	0	0
PUBREL	Reserved	0	0	1	0
PUBCOMP	Reserved	0	0	0	0
SUBSCRIBE	Reserved	0	0	1	0
SUBACK	Reserved	0	0	0	0
UNSUBSCRIBE	Reserved	0	0	1	0
UNSUBACK	Reserved	0	0	0	0
PINGREQ	Reserved	0	0	0	0
PINGRESP	Reserved	0	0	0	0
DISCONNECT	Reserved	0	0	0	0





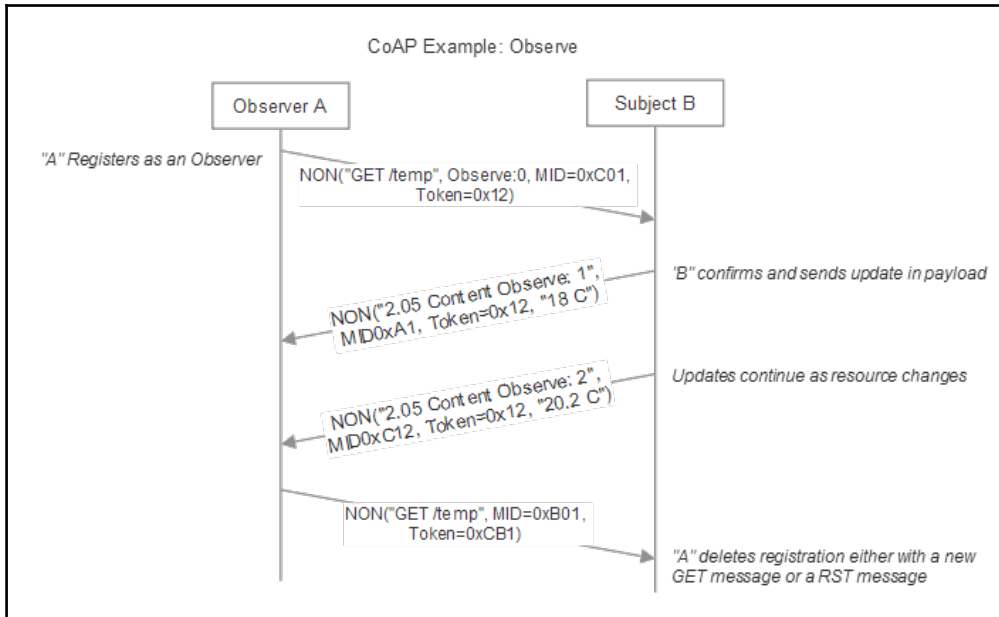
Time	CoAP Message	MID	Token	Options	Payload
9:09:50 PM	CON-GET	12514 (0)	empty	Uri-Path: .well-known/core, Block2: 0/0/64	
9:09:50 PM	ACK-2.05 Content	12514	empty	Content-Format: 40, Block2: 0/1/64, Size2: 1918	</obs>;obs;rt="observe";title="Observable resource which changes
9:09:50 PM	CON-GET	12515 (0)	empty	Uri-Path: .well-known/core, Block2: 1/0/64	
9:09:50 PM	ACK-2.05 Content	12515	empty	Content-Format: 40, Block2: 1/1/64	every 5 seconds", </obs-pumping>;obs;rt="observe";title="Observe
9:09:50 PM	CON-GET	12516 (0)	empty	Uri-Path: .well-known/core, Block2: 2/0/64	
9:09:50 PM	ACK-2.05 Content	12516	empty	Content-Format: 40, Block2: 2/1/64	ble resource which changes every 5 seconds", </separate>;title="R
9:09:50 PM	CON-GET	12517 (0)	empty	Uri-Path: .well-known/core, Block2: 3/0/64	
9:09:50 PM	ACK-2.05 Content	12517	empty	Content-Format: 40, Block2: 3/1/64	esource which cannot be served immediately and which cannot be a
9:09:50 PM	CON-GET	12518 (0)	empty	Uri-Path: .well-known/core, Block2: 4/0/64	
9:09:50 PM	ACK-2.05 Content	12518	empty	Content-Format: 40, Block2: 4/1/64	cknowledged in a piggy-backed way", </large-create>;rt="block";ti

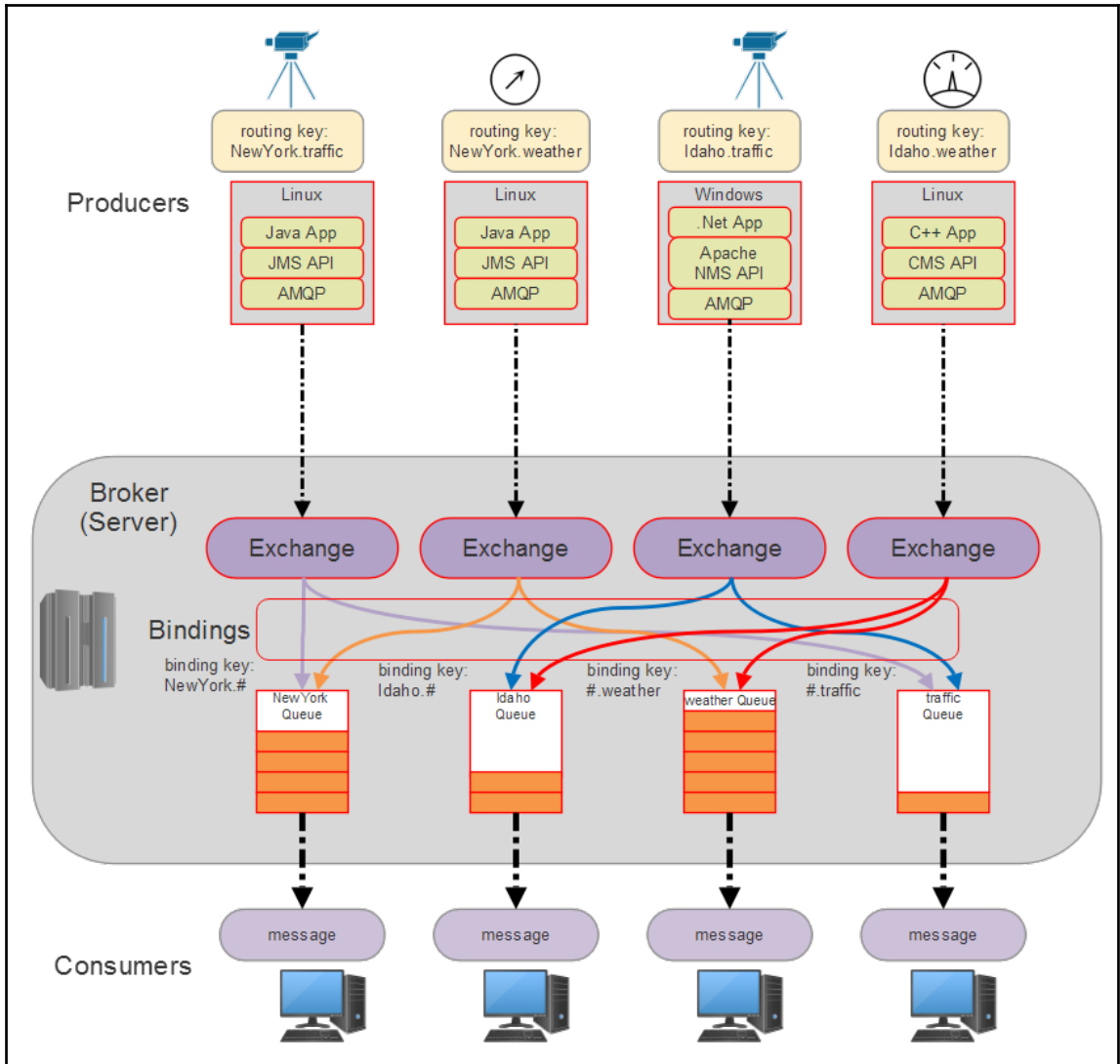


CoAP Message Structure

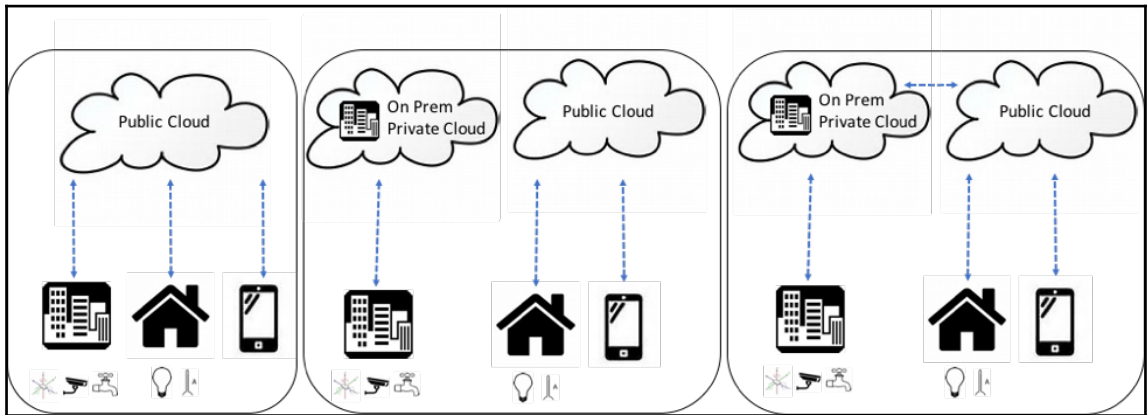
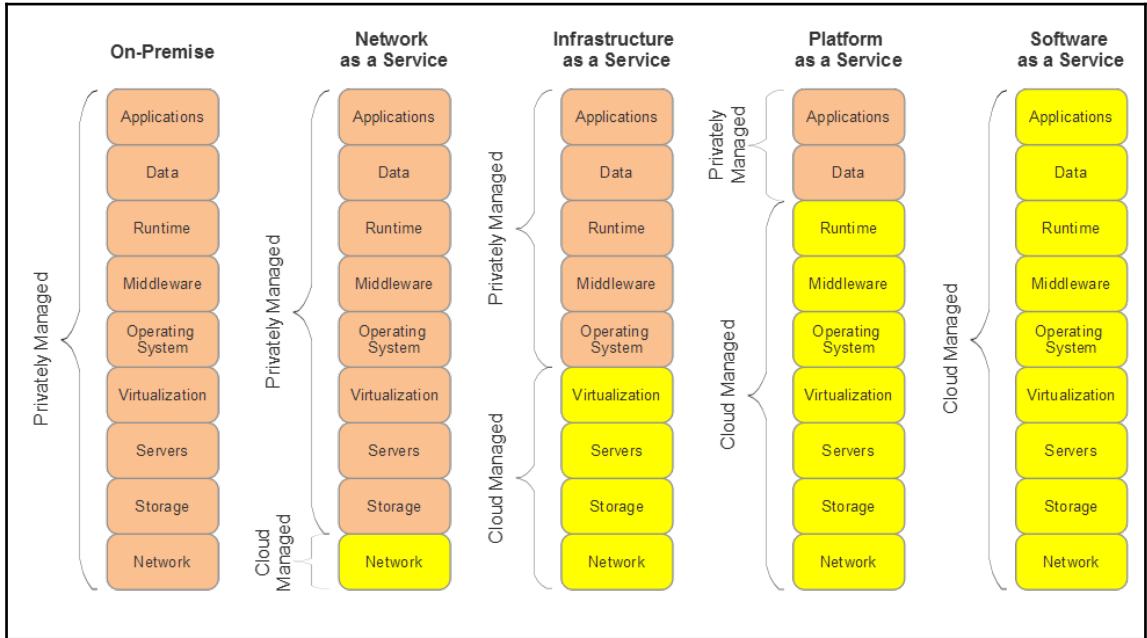
bit position		0-1	2-3	4 to 7	8 to 15	16 to 31
Version	Message Type (T)	Token Length (TKL)		Code	Message ID	
Token (optional - 0 to 8 bytes)						
Options (if any)						
Reserved (11111111)				Payload (optional)		

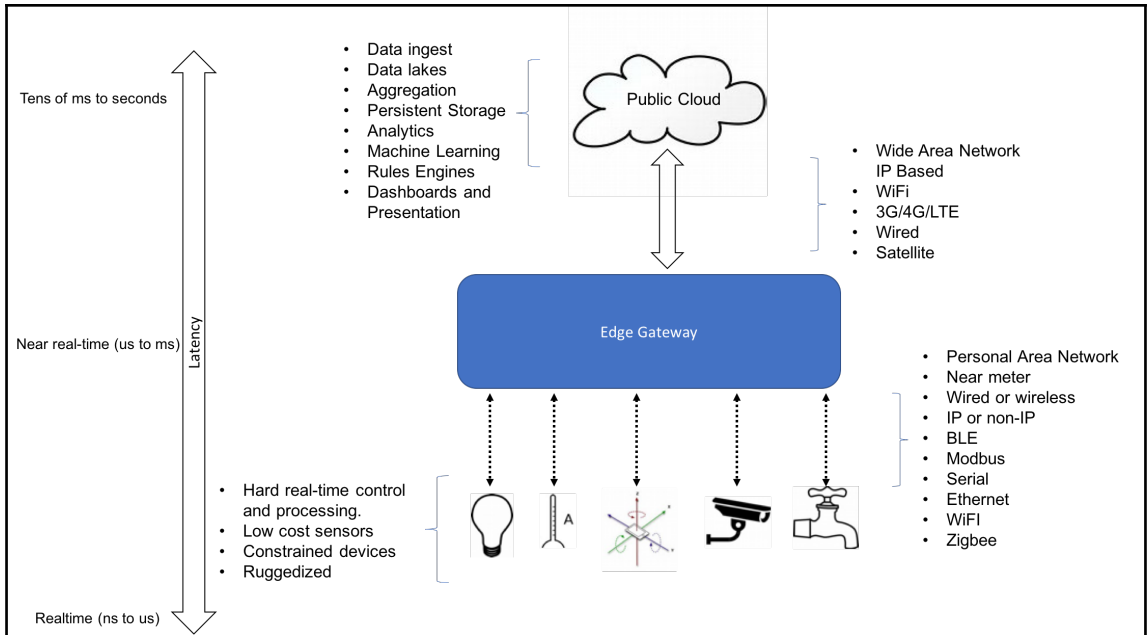
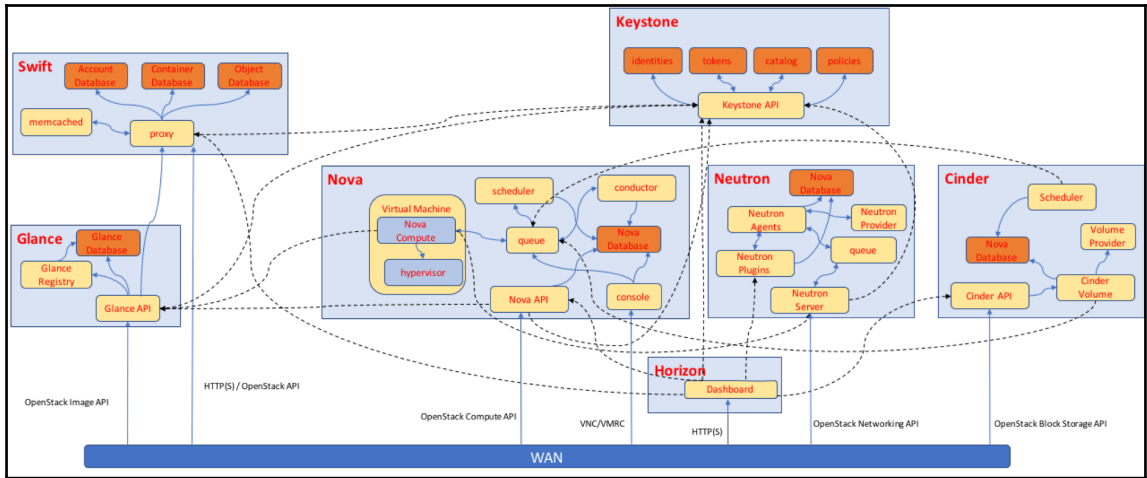
- **Version:** 2-bit integer, set to 1. Future versions may differ.
- **Message Type:** 2-bit identifier: CON(0), NON(1), ACK(2), RST(3).
- **Token Length:** Length of variable-length token field.
- **Code:** 8-bit indicator of success, failures, and errors.
- **Message ID:** 16-bit unsigned int used to detect duplicate messages
- **Token:** 0 to 8 bytes used to correlate requests to responses.
- **Options:** Request and response optional parameters such as: URI information, max-age, Content, and Etags
- **Payload:** (optional) data or message, can be zero length

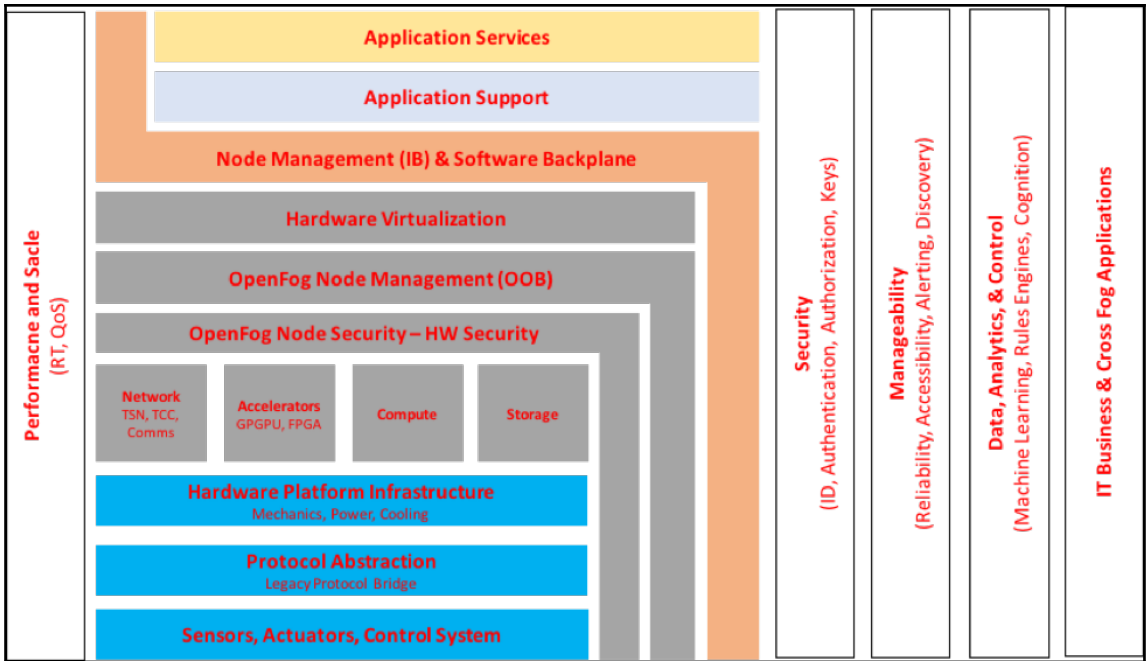
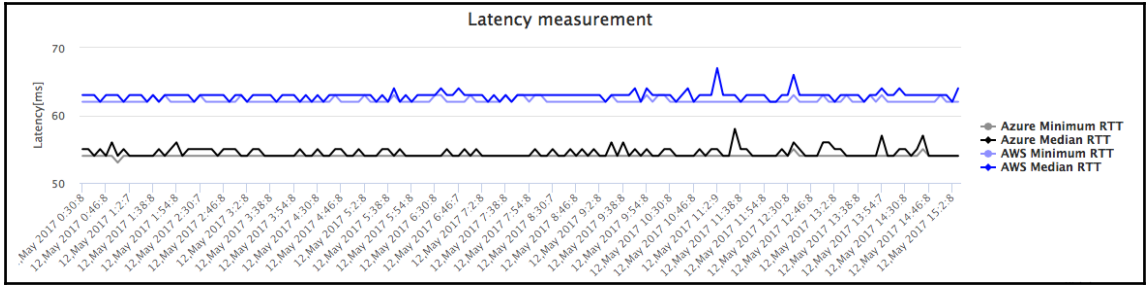


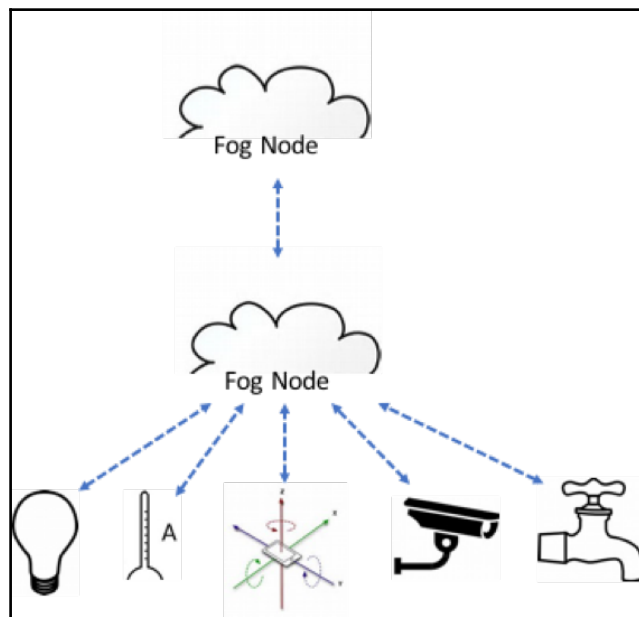
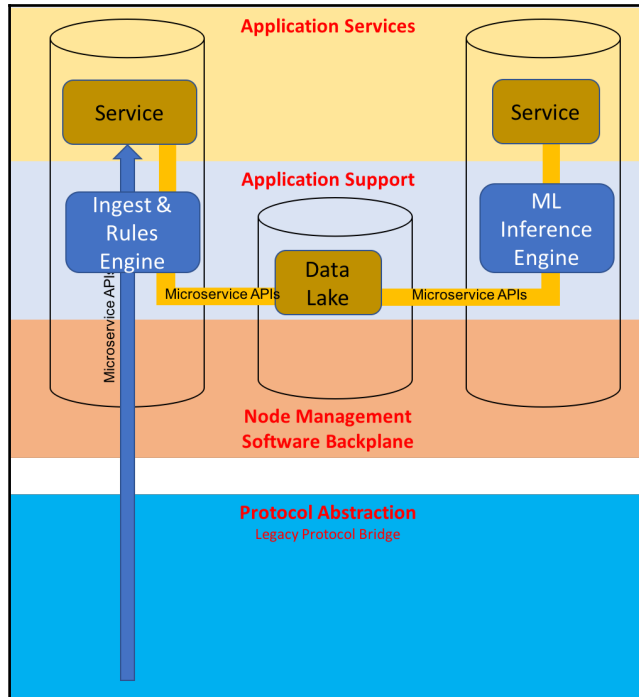


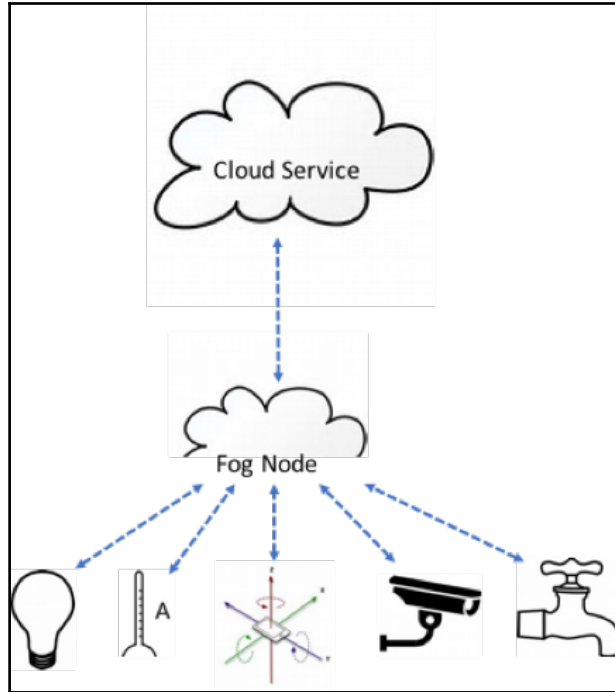
Chapter 10: Cloud and Fog Topologies

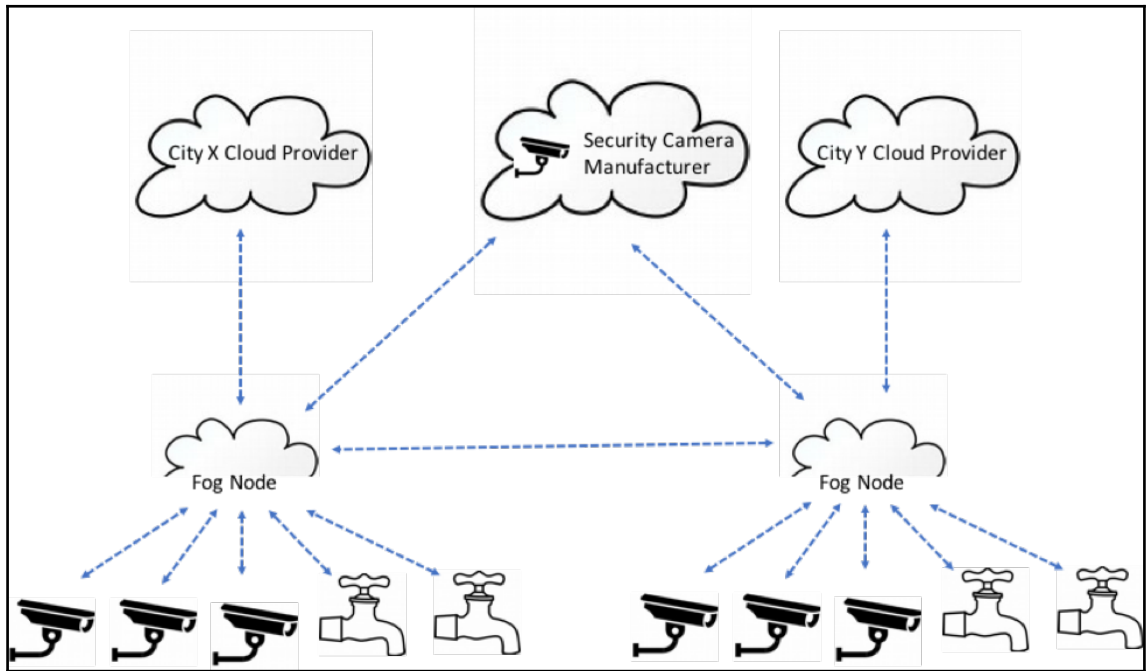
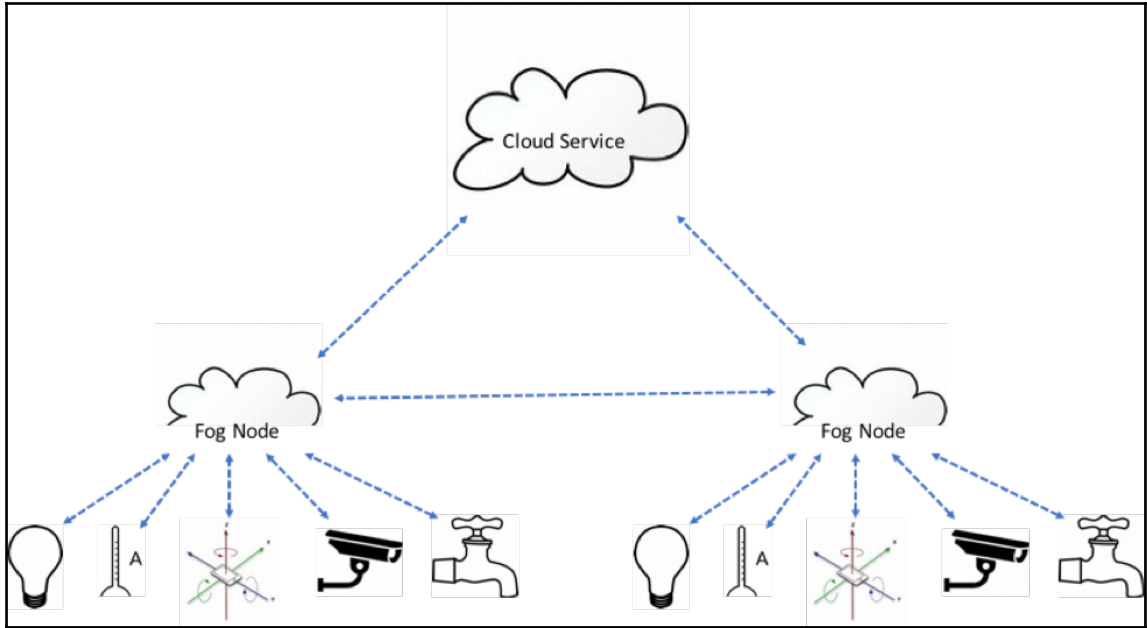


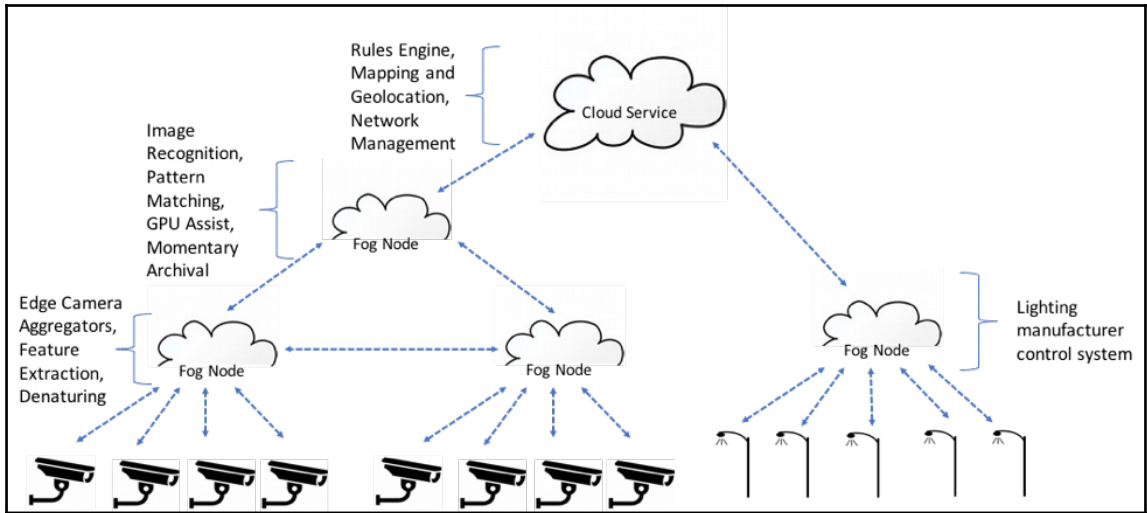




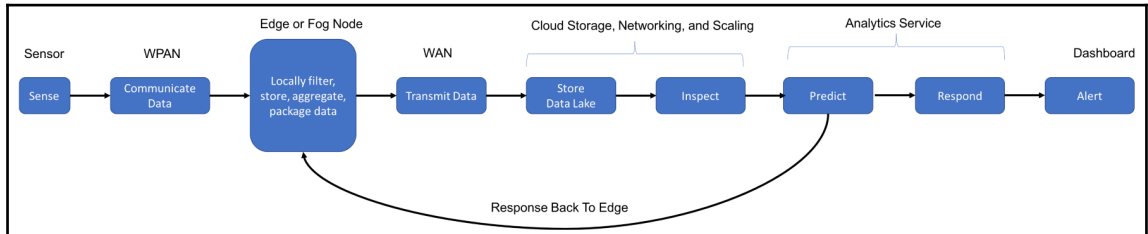








Chapter 11: Data Analytics and Machine Learning in the Cloud and in the Fog



$$C = \text{Cluster capacity} \left(\frac{\text{events}}{s} \right)$$

R_{event} = Event rate

T_{burst} = Time of burst of events

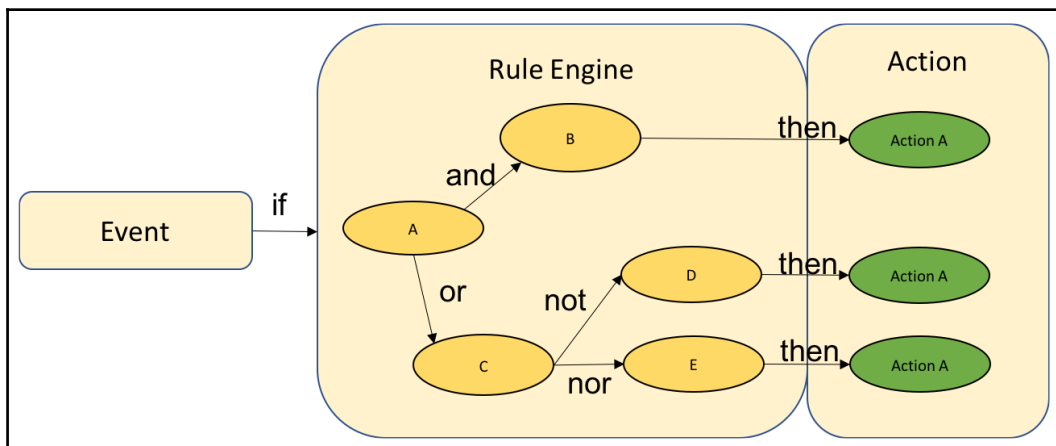
T_c = Time to complete backlog

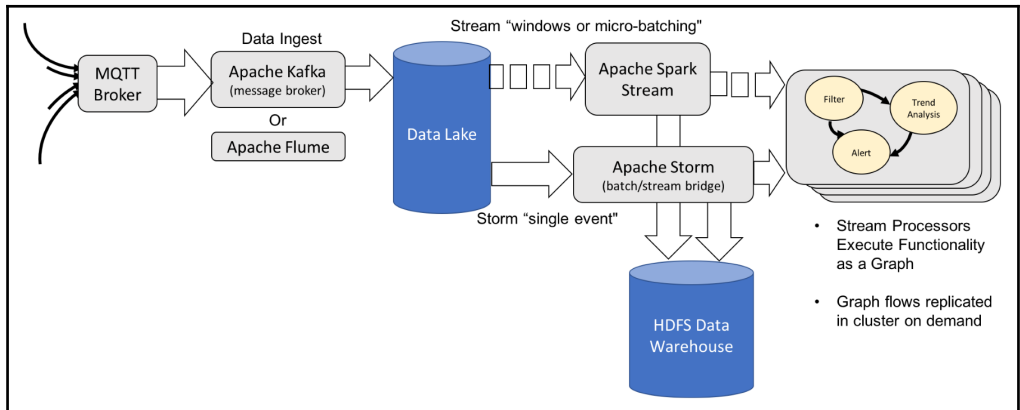
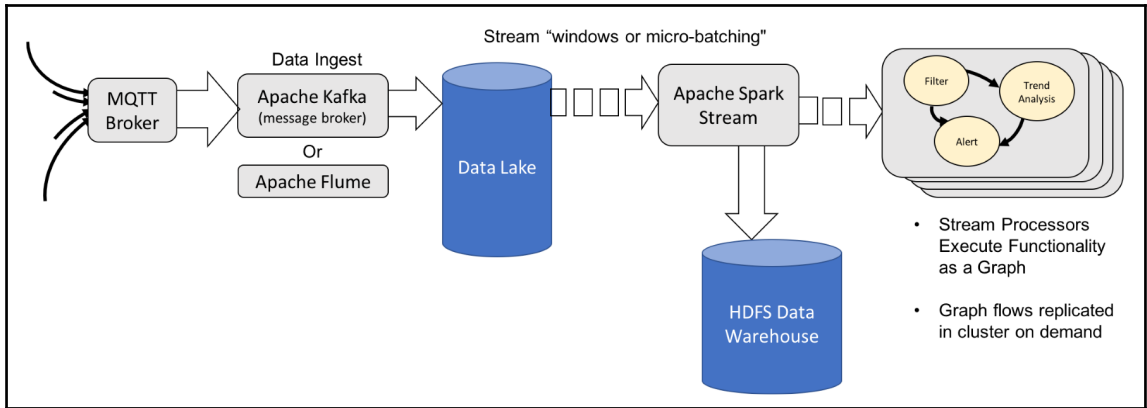
M_{backlog} = Message backlog (size)

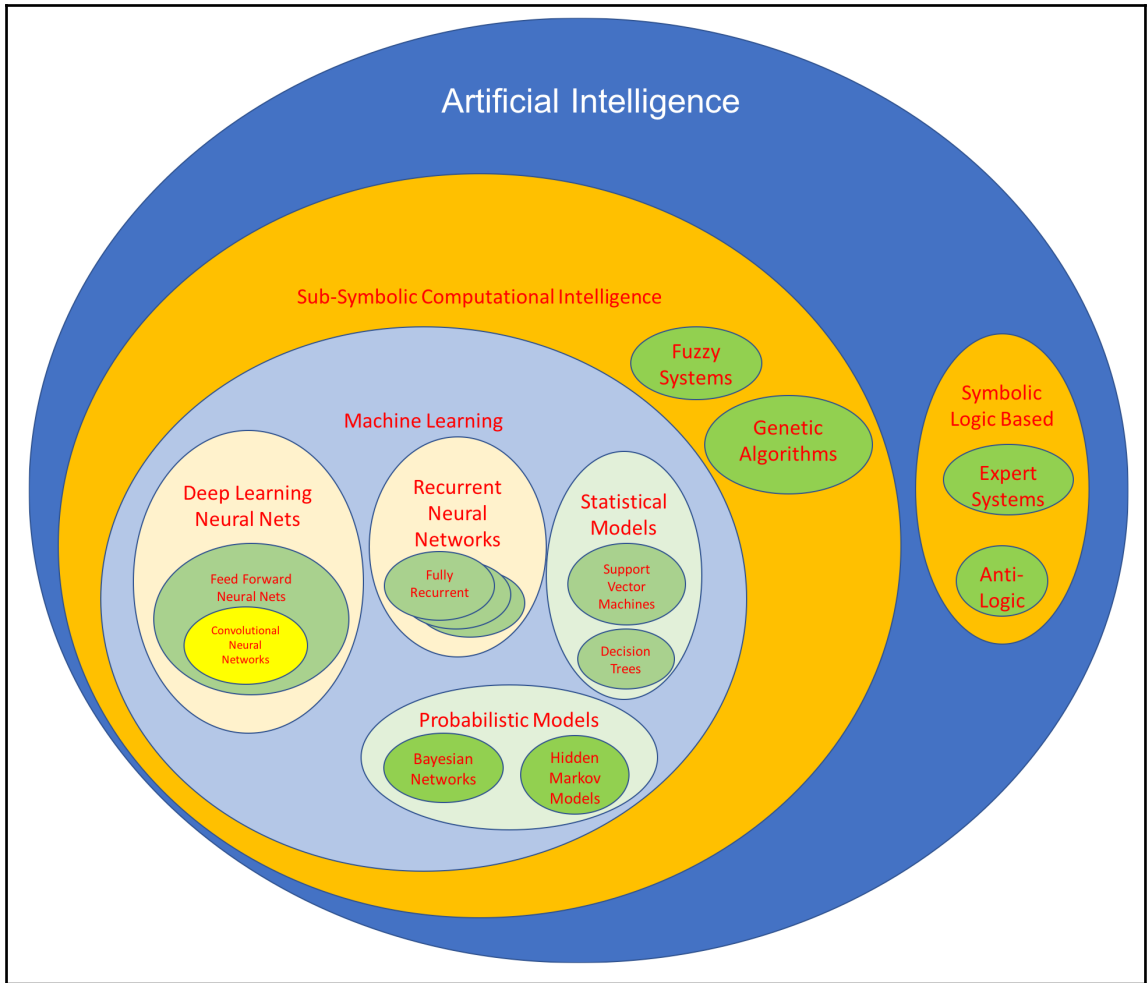
$$\text{Backlog} = \begin{cases} 0 & \text{where } R_{\text{event}} \leq C \\ R_{\text{event}} - C & \text{where } R_{\text{event}} > C \end{cases}$$

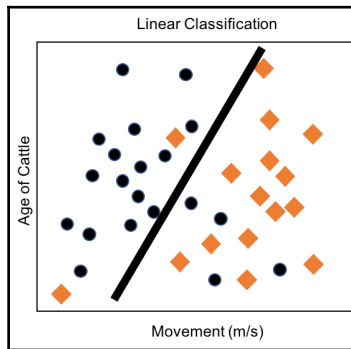
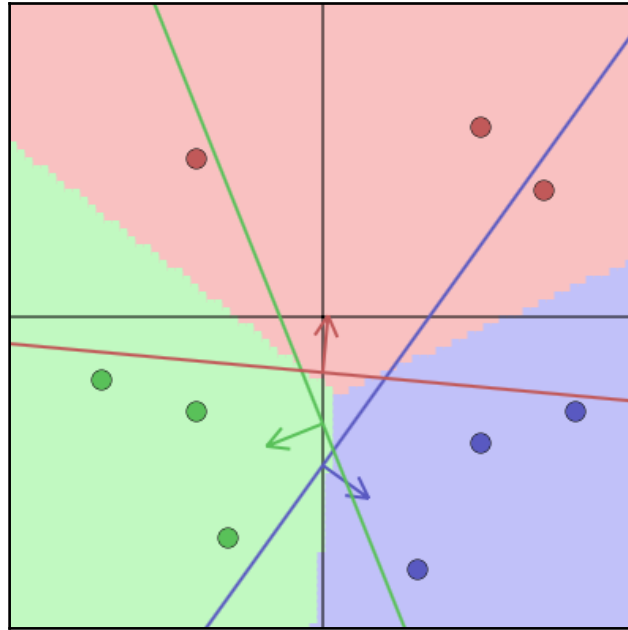
$$M_{\text{backlog}} = \text{Backlog} \times M_{\text{size}}$$

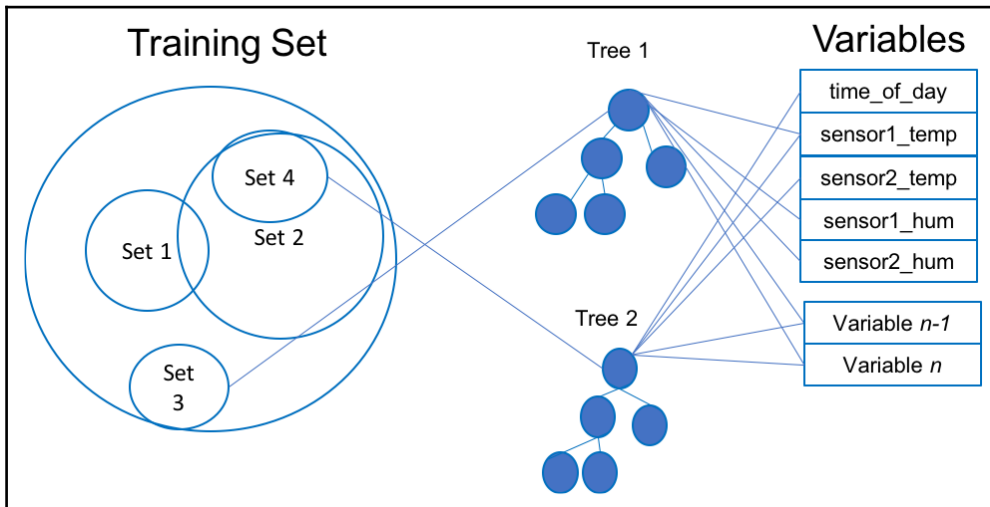
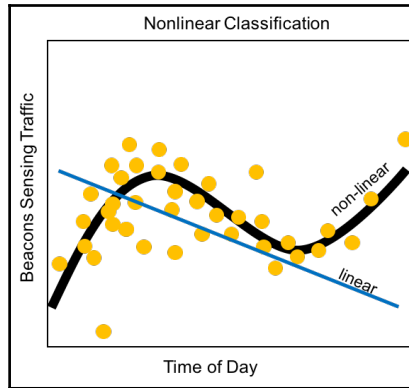
$$T_c = \frac{(R_{\text{event}} \times T_{\text{burst}}) + M_{\text{backlog}}}{C}$$

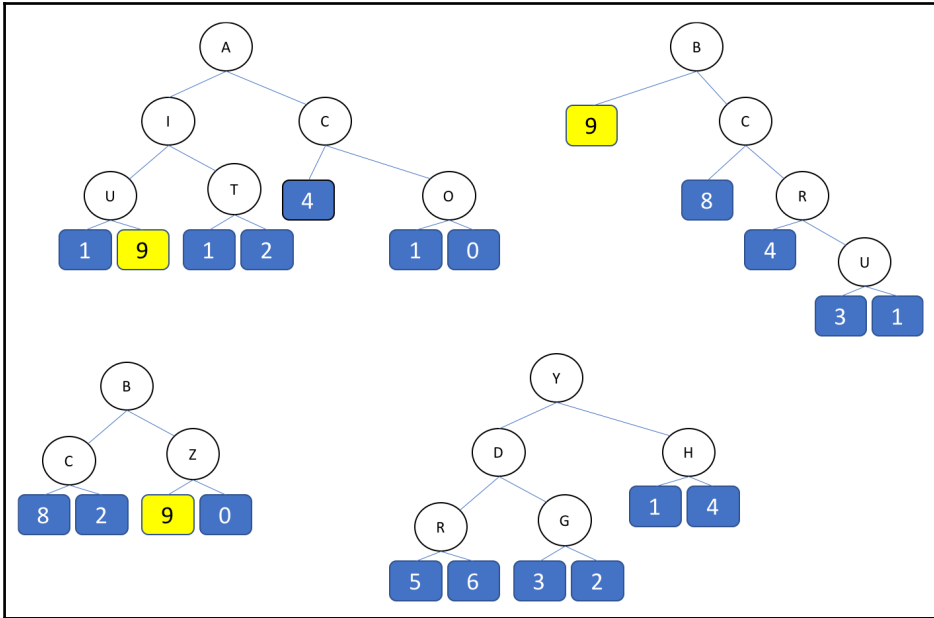












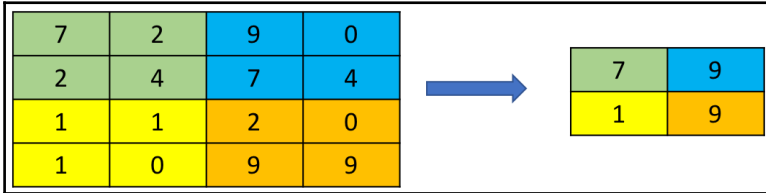
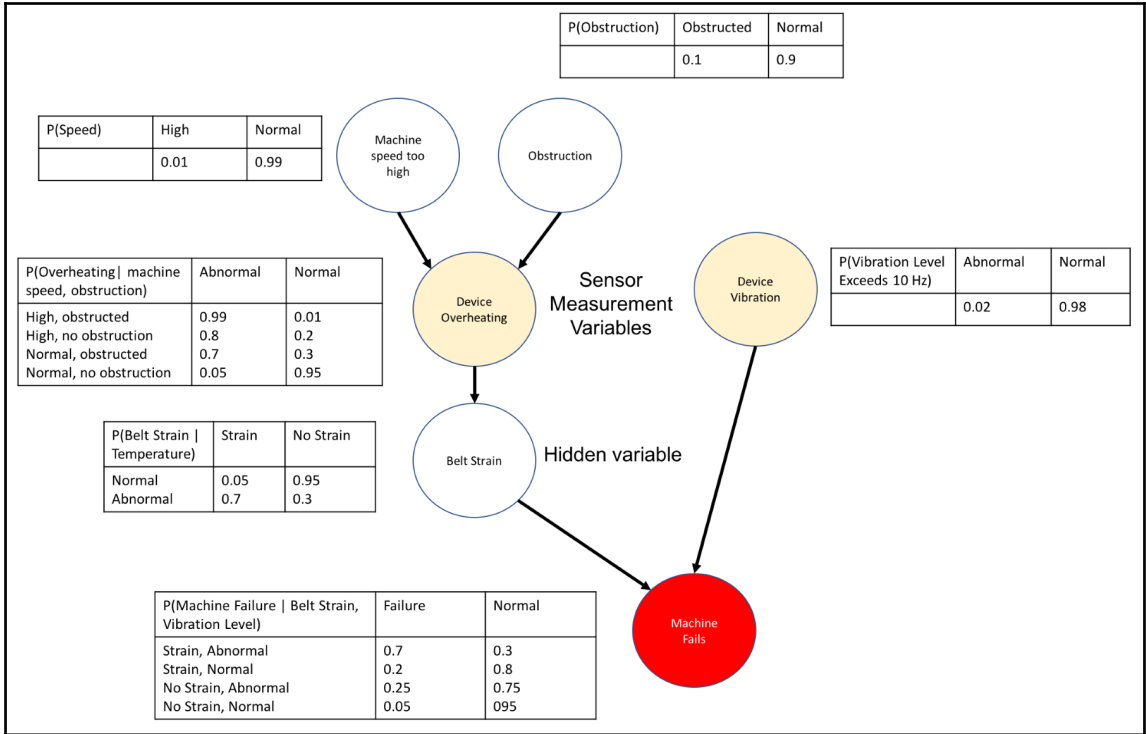
$$P(A|B) = \frac{P(A \cap B)}{P(B)}$$

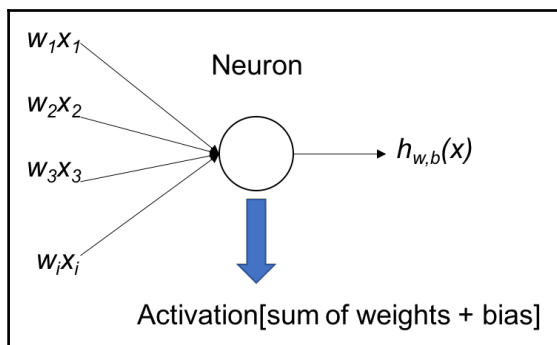
$$P(A_i|B) = \frac{P(B|A_i) \times P(A_i)}{P(B|A_1) \times P(A_1) + P(B|A_2) \times P(A_2) + \dots + P(B|A_i) \times P(A_i)}$$

$$P(A|B) = \frac{P(B|A) \times P(A)}{P(B|A) \times P(A) + P(B|A') \times P(A')}$$

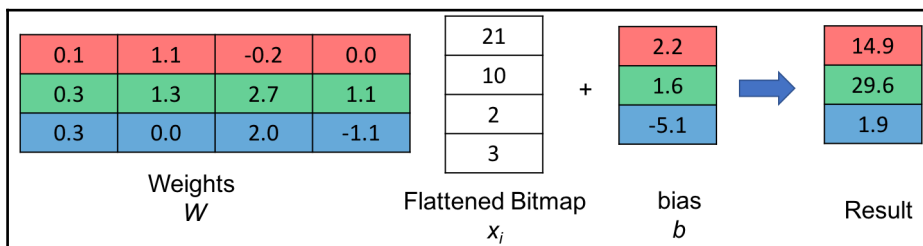
$$P(A|F) = \frac{P(F|A) \times P(A)}{P(F|A) \times P(A) + P(F|B) \times P(B)}$$

$$P(A|F) = \frac{0.02 \times 0.7}{(0.02 \times 0.7) + (0.04 \times 0.3)}$$

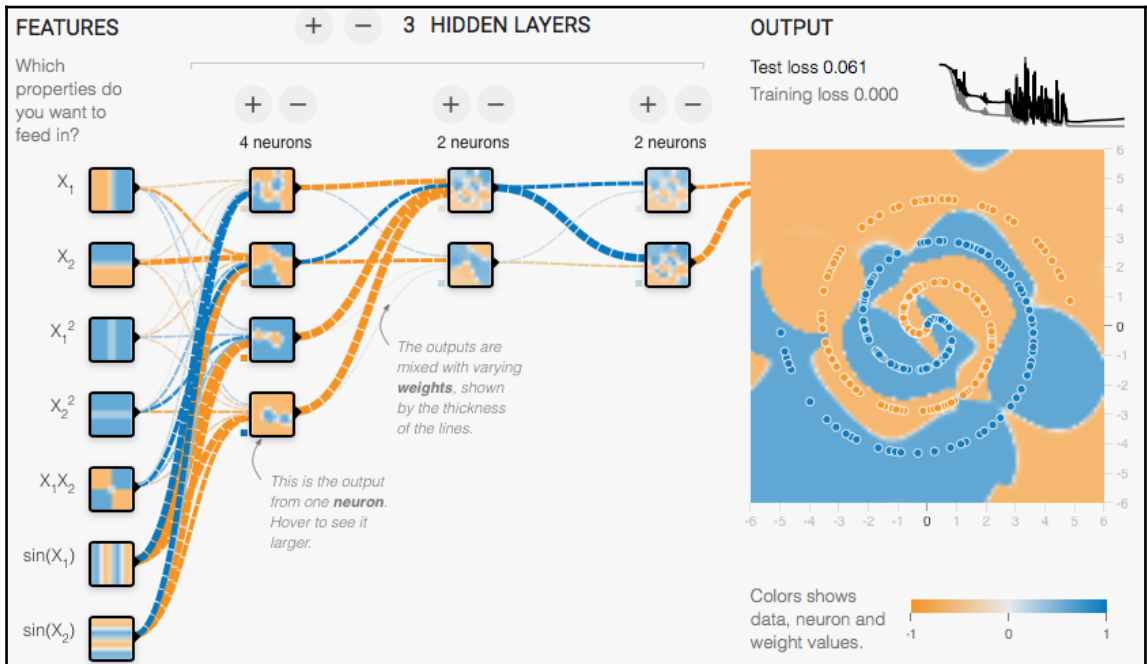
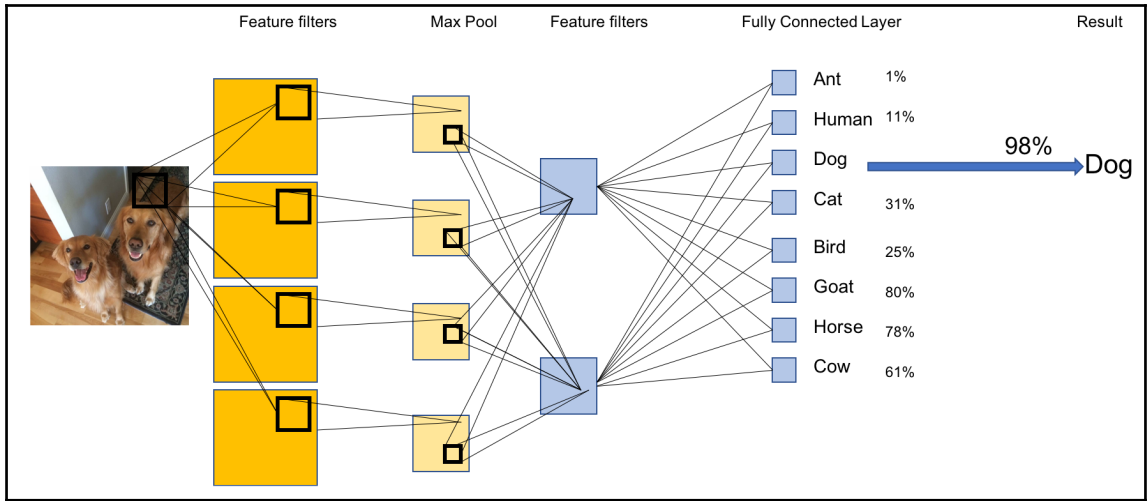


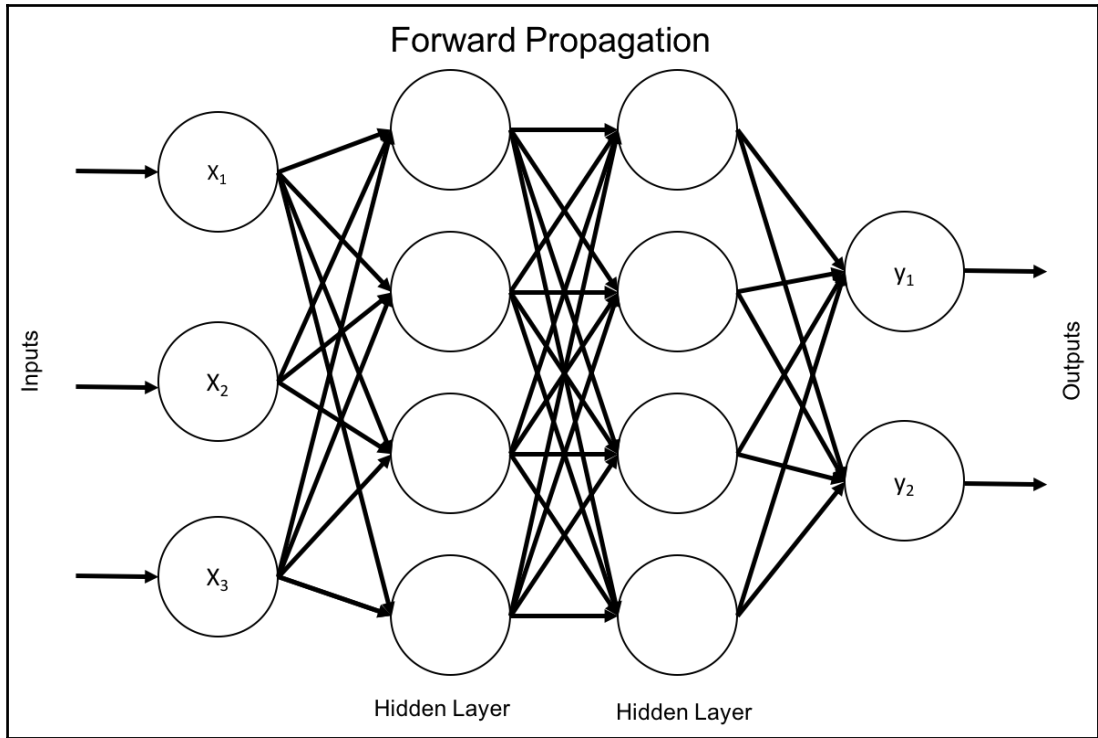


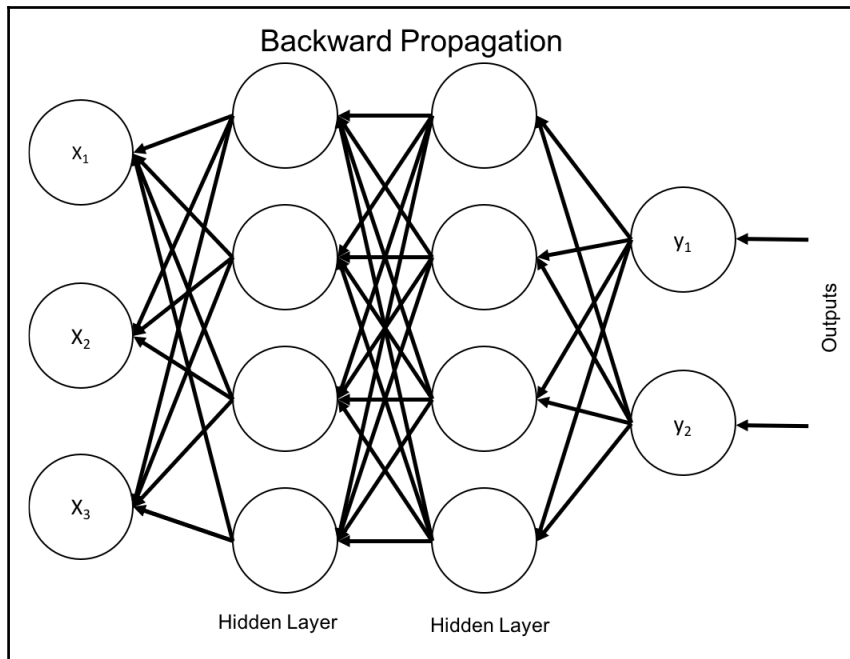
$$\sigma \left(\sum_i w_i x_i + b \right)$$



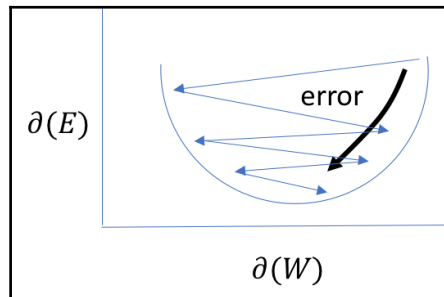
$$\sigma(x) = \frac{1}{(1 + e^{-x})}$$

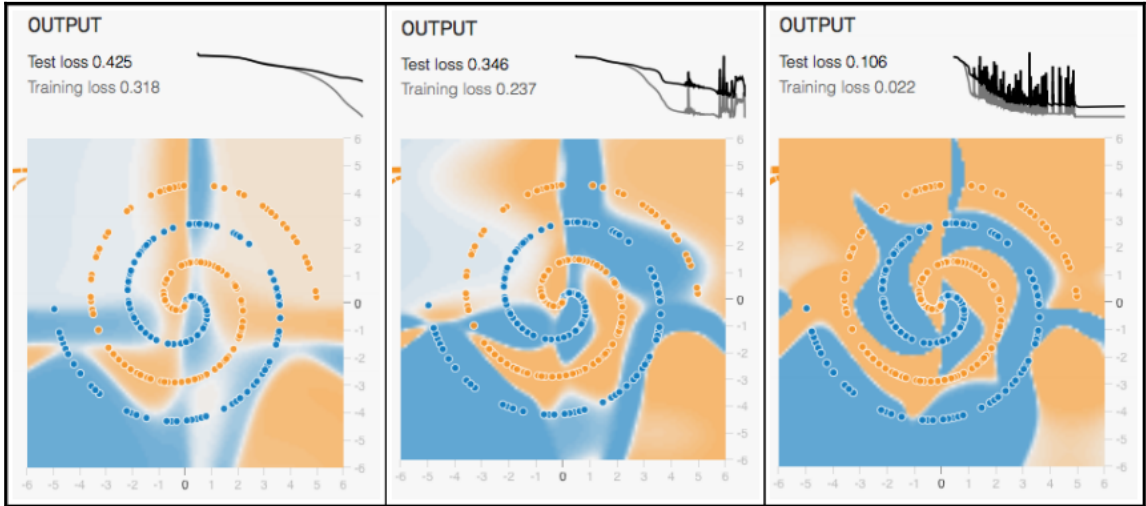
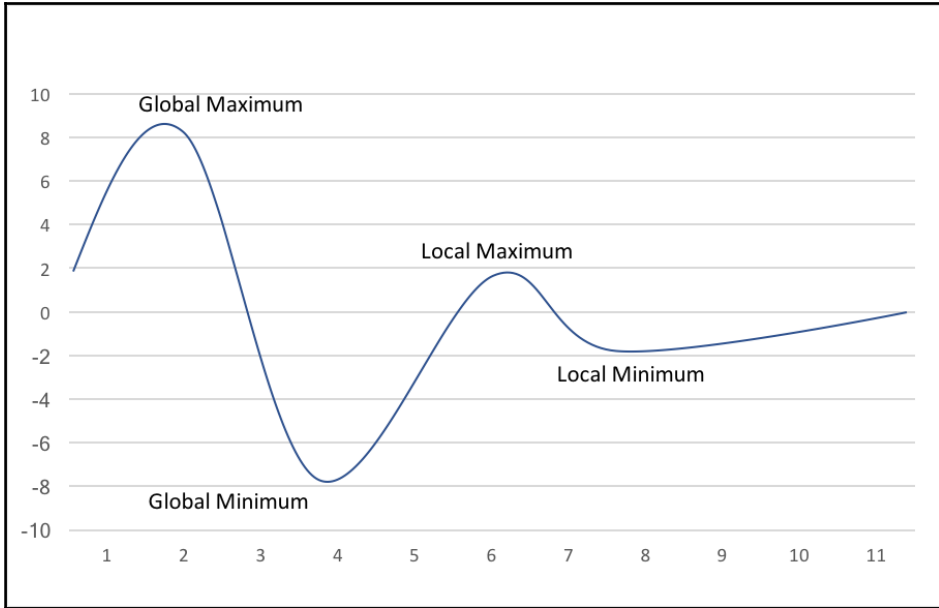


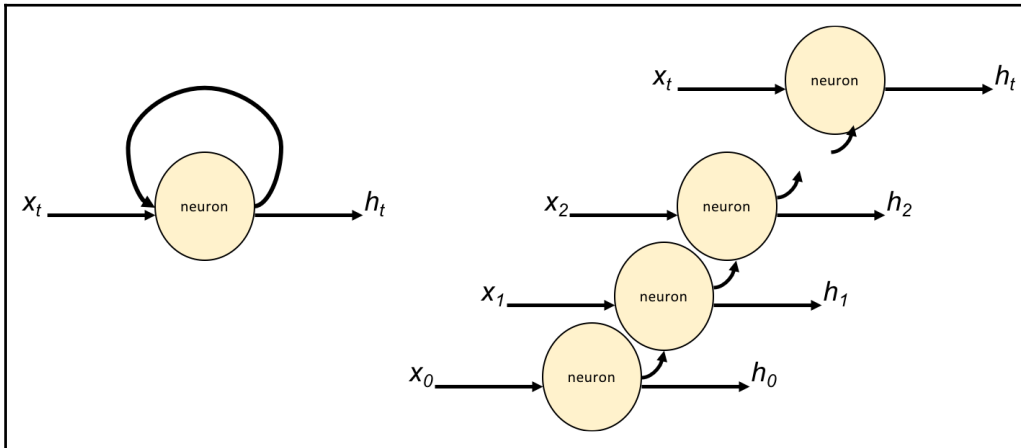
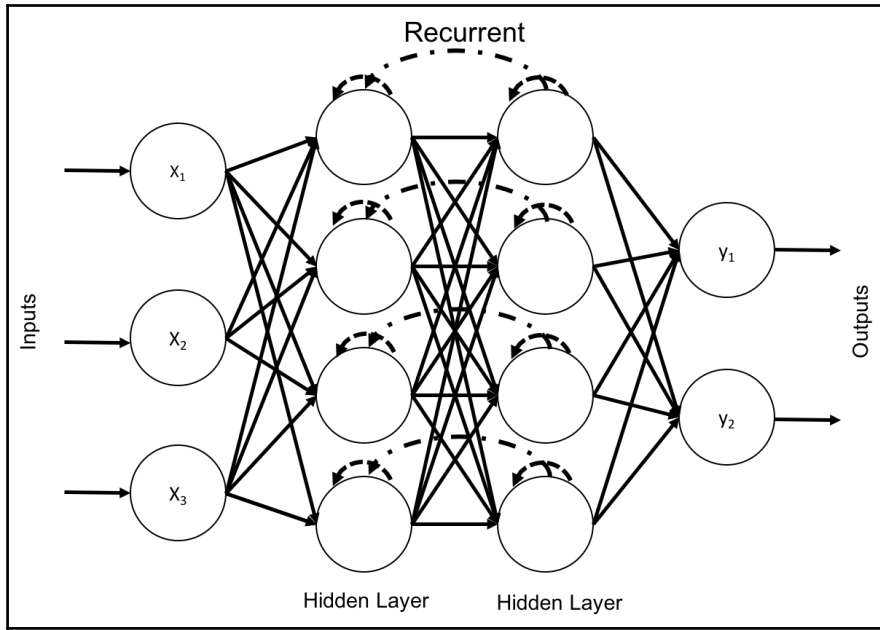


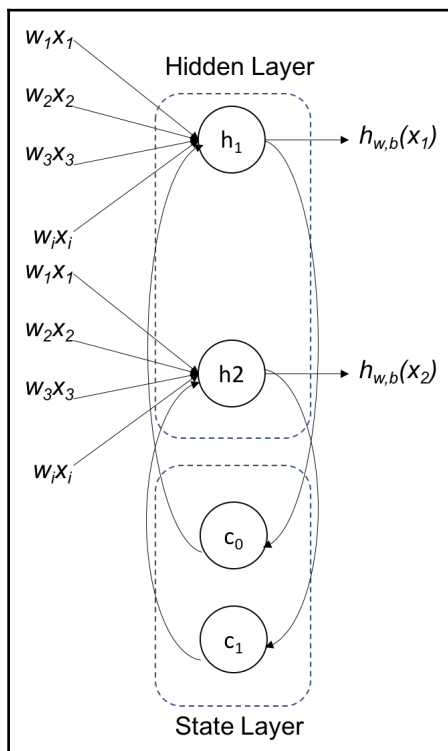
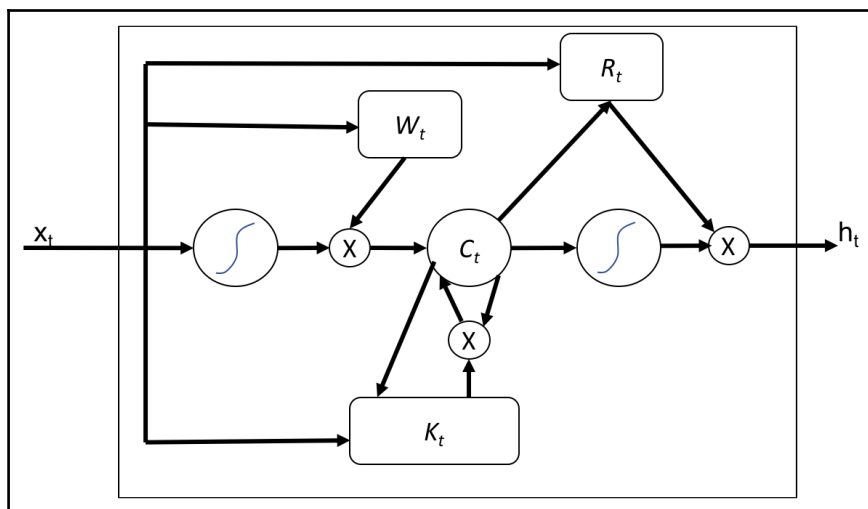


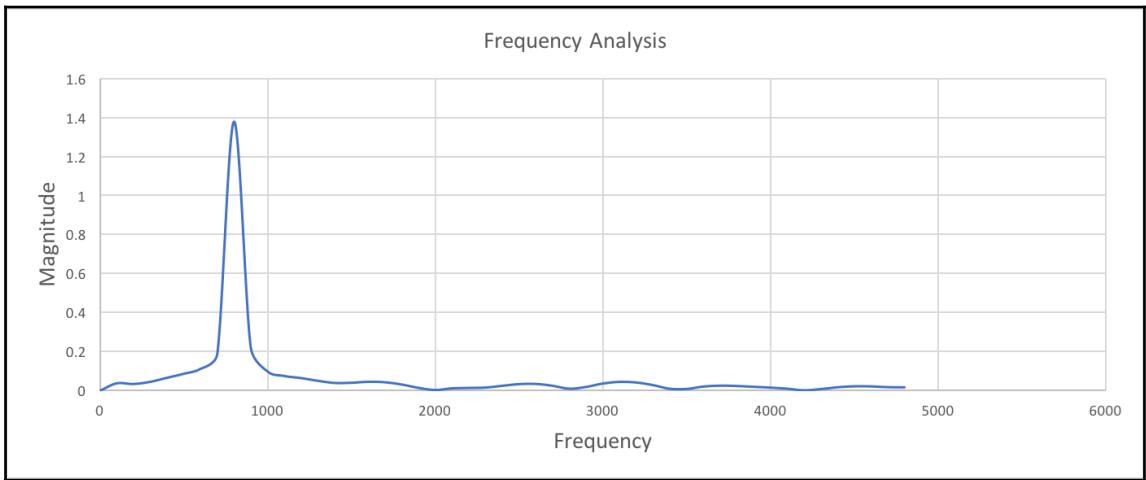
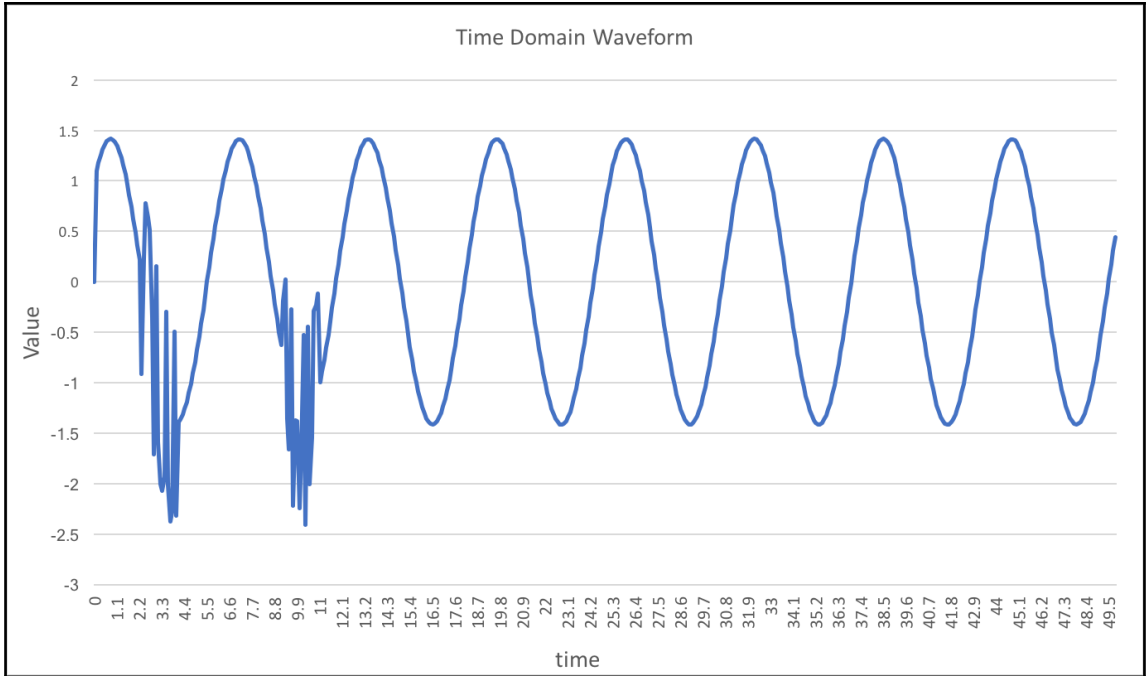
$$W(t) = W(t - 1) - \lambda \times \left(\frac{-\partial E}{\partial W}(t) \right)$$



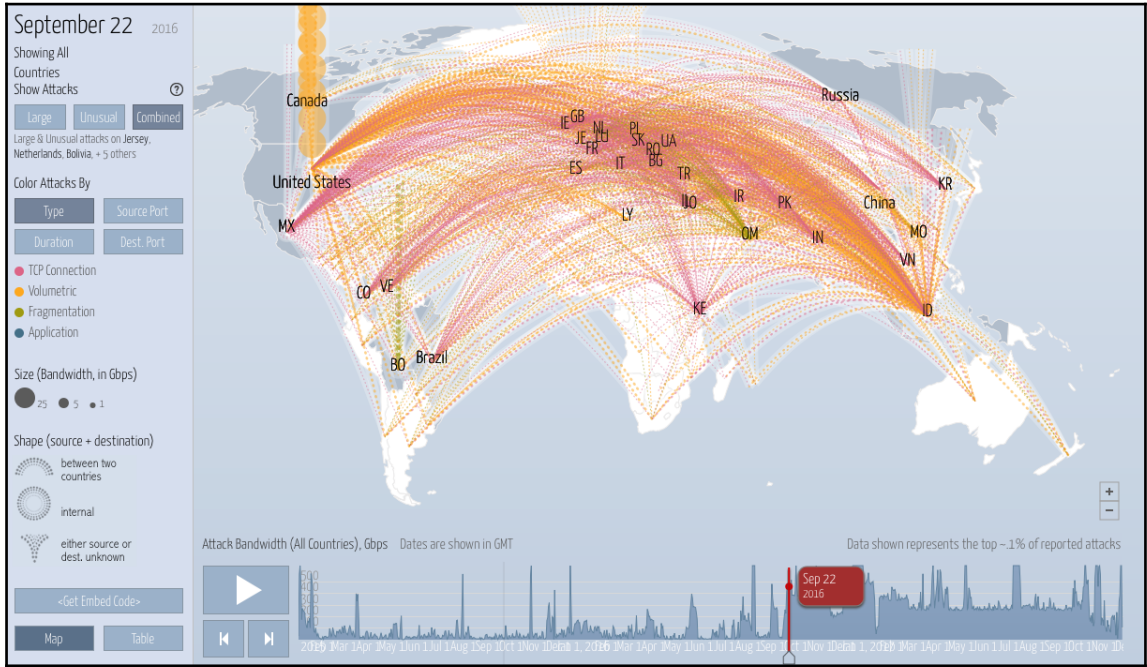


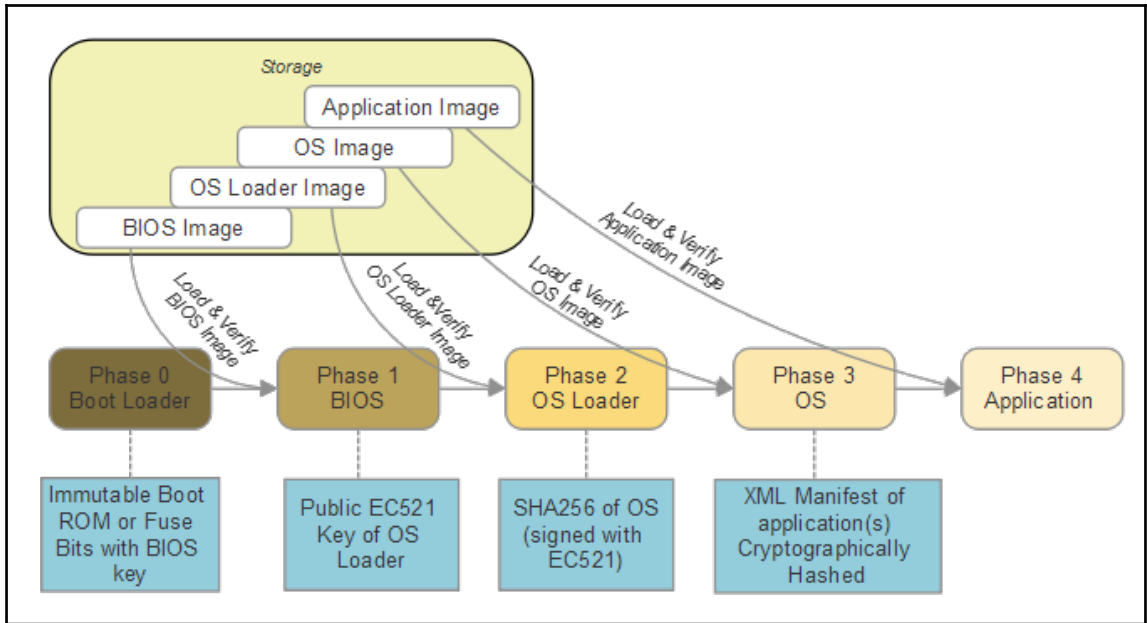


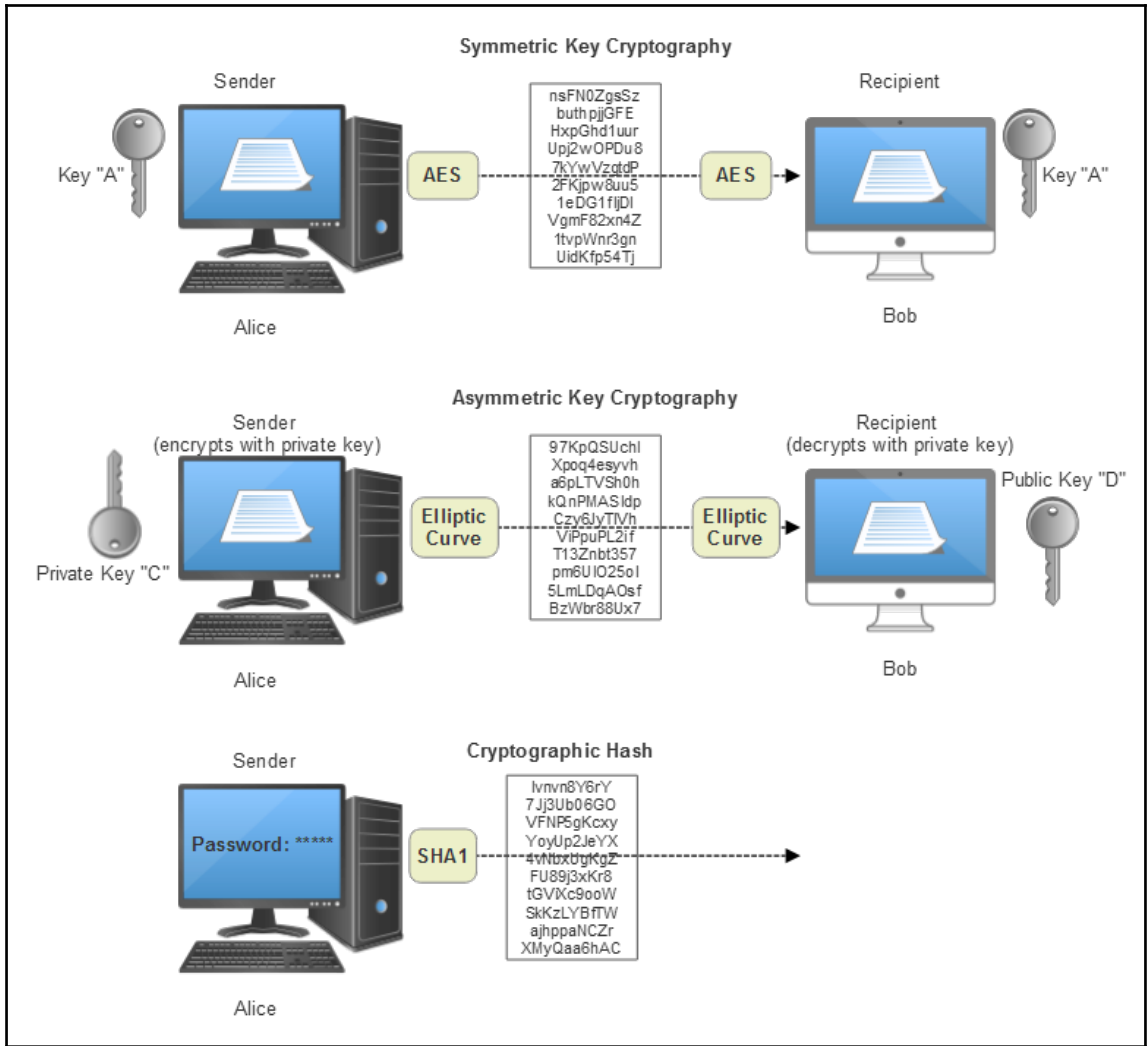


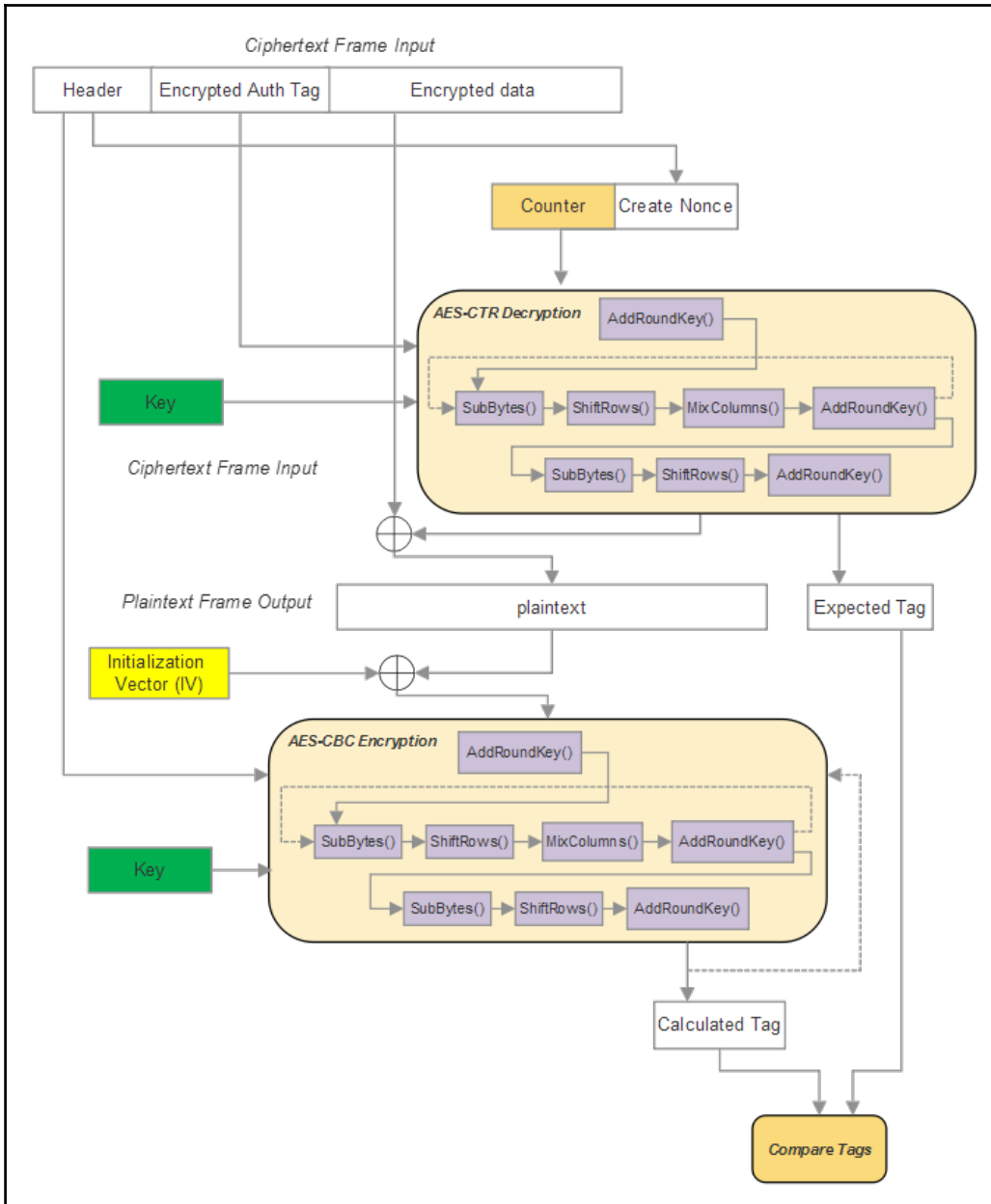


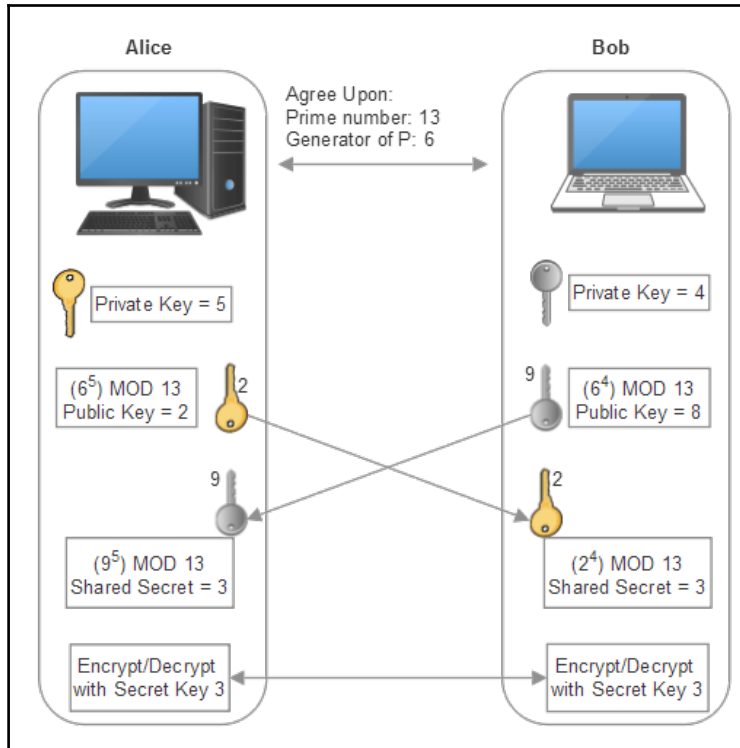
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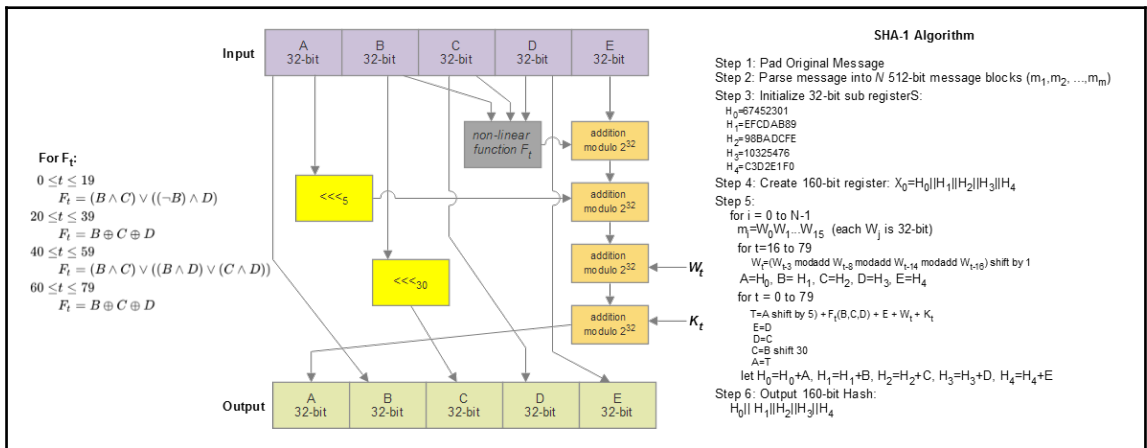
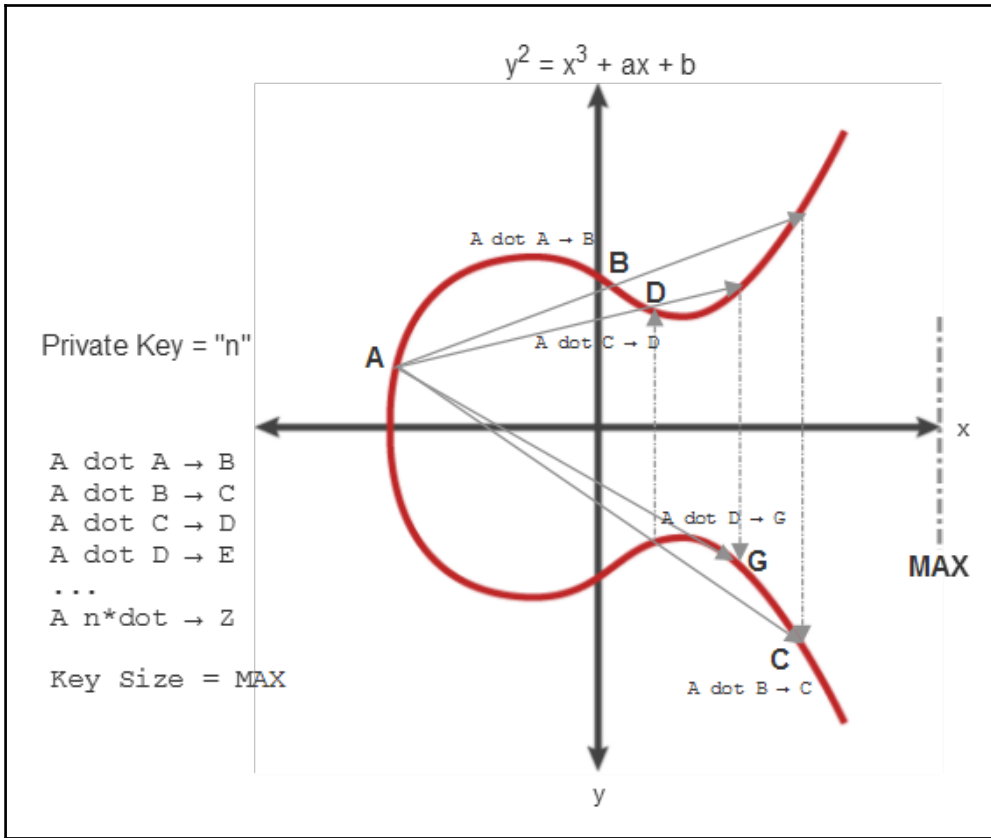


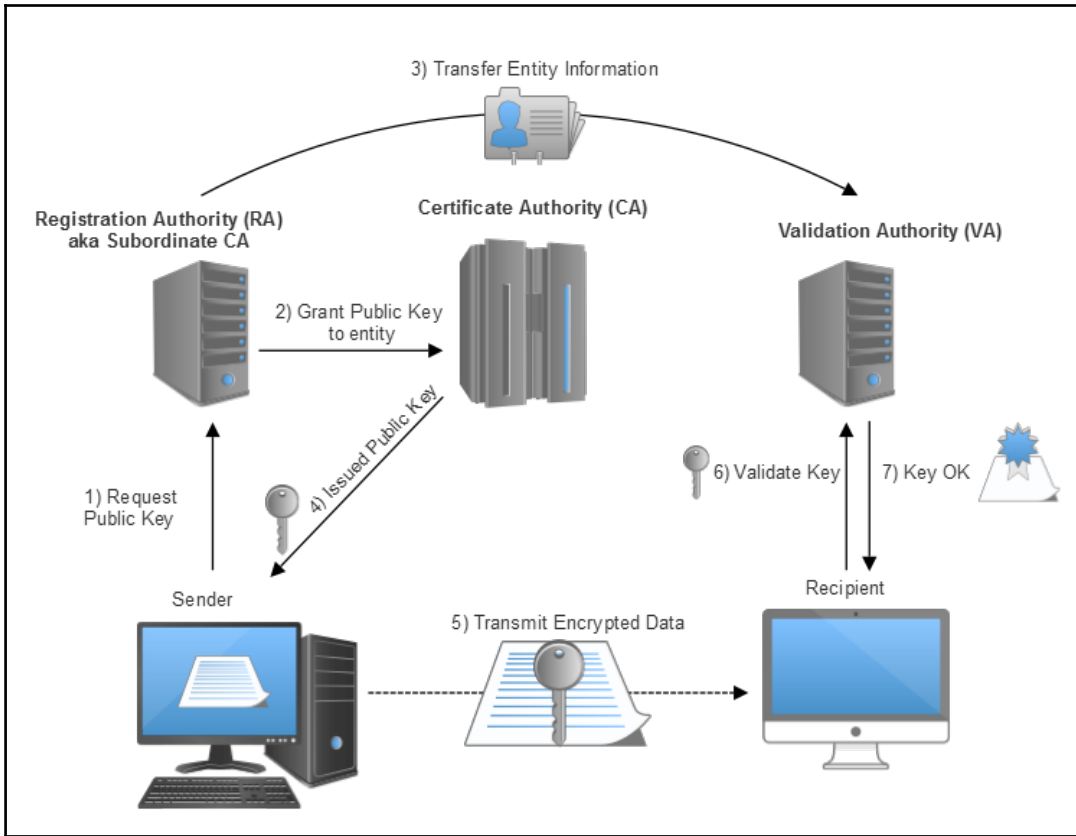


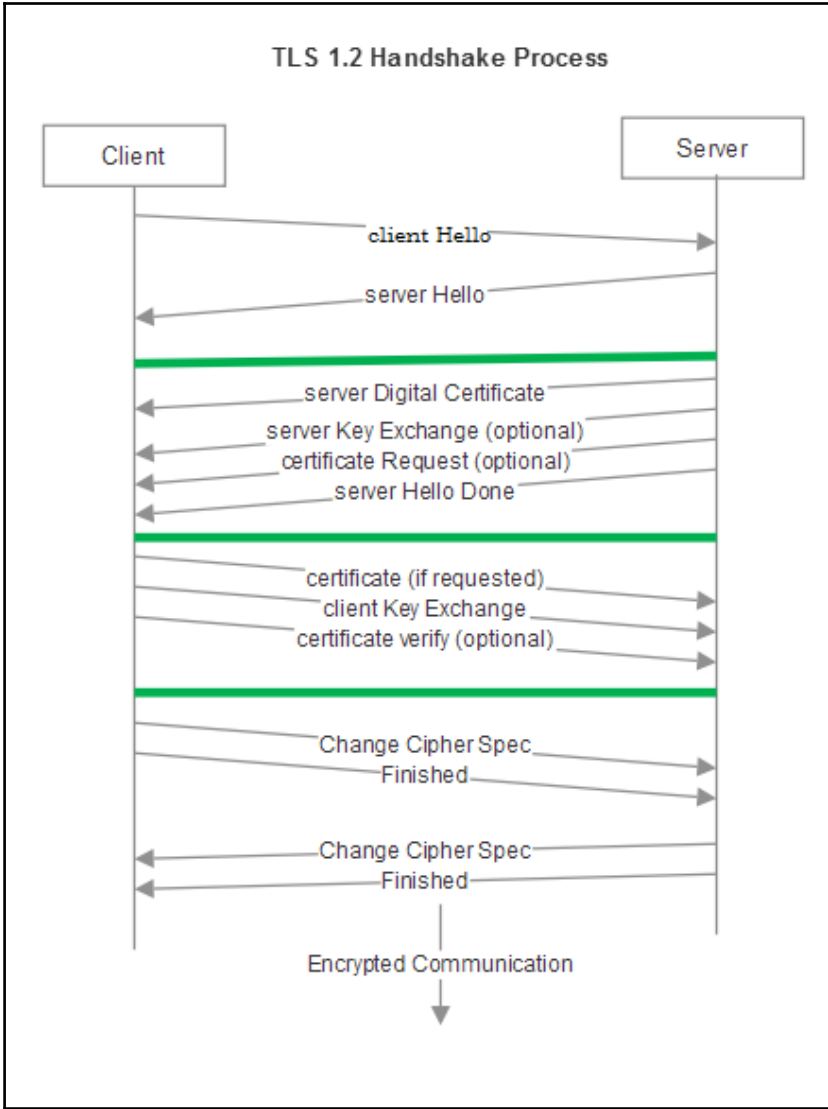


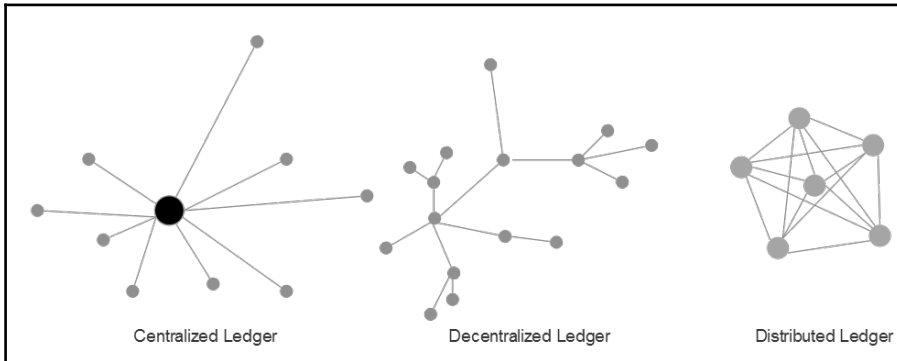
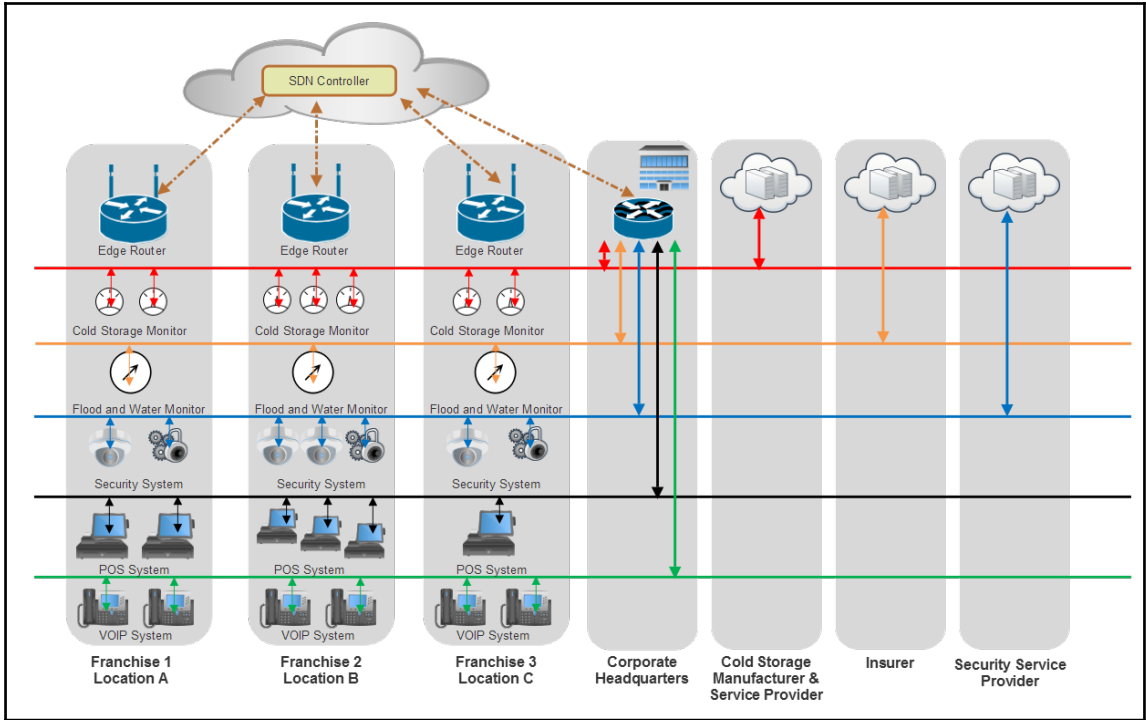


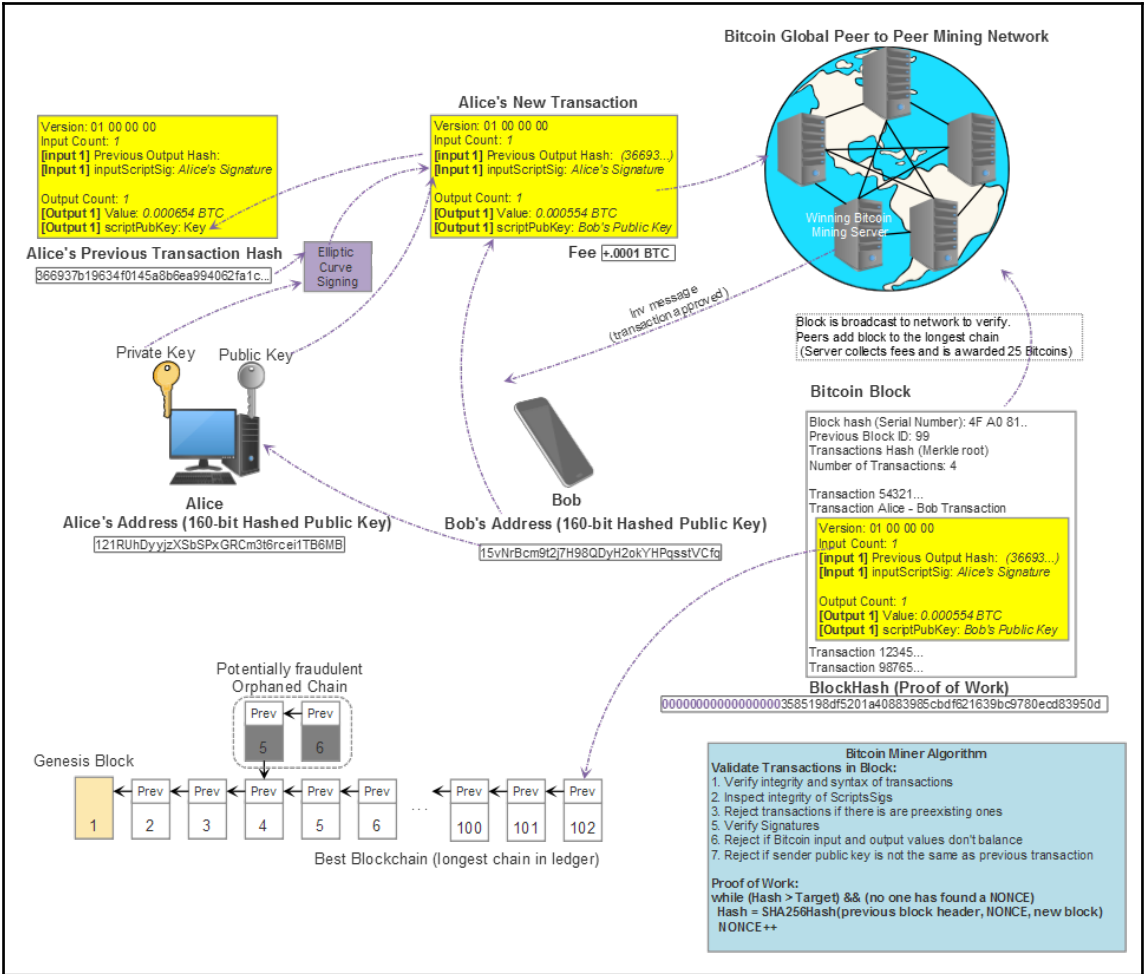












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