# WIRELESS COMUNICATION ECE3400, Fall 2017







![](_page_3_Picture_0.jpeg)

![](_page_3_Picture_1.jpeg)

# ABSTRACTION HIERARCHY

![](_page_4_Picture_1.jpeg)

![](_page_5_Figure_0.jpeg)

![](_page_5_Picture_1.jpeg)

Layers of Abstraction

![](_page_5_Picture_3.jpeg)

![](_page_6_Figure_0.jpeg)

![](_page_6_Picture_4.jpeg)

- Physics
- Layers of Abstraction

![](_page_6_Figure_16.jpeg)

![](_page_6_Picture_17.jpeg)

![](_page_7_Picture_0.jpeg)

# RADIO

![](_page_7_Picture_2.jpeg)

![](_page_8_Picture_0.jpeg)

#### 1950S VOCABULARY

► "intelligence" == "information"

"cycles" == "hertz"\*

\*(adopted by the General Conference on Weights and Measures in 1960)

![](_page_8_Picture_5.jpeg)

![](_page_9_Picture_0.jpeg)

#### 1950S VOCABULARY

"intelligence" == "information"

"cycles" == "hertz"\*

\*(adopted by the General Conference on Weights and Measures (CGPM) in 1960)

![](_page_9_Picture_5.jpeg)

# AMPLITUDE MODULATION (AM)

![](_page_11_Picture_0.jpeg)

![](_page_11_Picture_1.jpeg)

![](_page_12_Picture_0.jpeg)

#### AMPLITUDE Manadas ATION (AM)

- Disadvantages?
- ► How do we fix it?

![](_page_13_Picture_0.jpeg)

# FREQUENCY MODULATION (FM)

![](_page_14_Picture_1.jpeg)

![](_page_15_Picture_0.jpeg)

![](_page_15_Picture_1.jpeg)

![](_page_16_Figure_0.jpeg)

# 

### FREQUENCY Manages ATION (FM)

Disadvantages?

![](_page_17_Picture_1.jpeg)

## UNITED

#### STATES FREQUENCY ALLOCATIONS THE RADIO SPECTRUM

RADIO SERVICES COLOR LEGEND									
AERONAUTICAL MOBILE		INTER-SATELLITE		RADIO ASTRONOMY					
AERONAUTICAL MOBILE SATELLITE		LAND MOBILE		RADIODETERMINATION SATELLITE					
AERONAUTICAL RADIONAVIGATION		LAND MOBILE SATELLITE		RADIOLOCATION					
AMATEUR		MARITIME MOBILE		RADIOLOCATION SATELLITE					
AMATEUR SATELLITE		MARITIME MOBILE SATELLITE		RADIONAVIGATION					
BROADCASTING		MARITIME RADIONAVIGATION		RADIONAVIGATION SATELLITE					
BROADCASTING SATELLITE		METEOROLOGICAL AIDS		SPACE OPERATION					
EARTH EXPLORATION SATELLITE		METEOROLOGICAL SATELLITE		SPACE RESEARCH					
FIXED		MOBILE		STANDARD FREQUENCY AND TIME SIGNAL					
FIXED SATELLITE		MOBILE SATELLITE		STANDARD FREQUENCY AND TIME SIGNAL SATELLITE					
ACTIVITY CODE									
GOVERNMENT EXCLUSI	VE	GOVERNME	NT/NON-GOV	(ERNMENT SHARED					
NON-GOVERNMENT EXC	CLUSIVE								

#### ALLOCATION USAGE DESIGNATION

SERVICE	EXAMPLE	DESCRIPTION
Primary	FIXED	Capital Letters
Secondary	Mobile	1st Capital with lower case letters

ო თ თ	4	30		53 90 110	5 130
NOT ALLOCATED	Fixed RADIONAVIGATION FIXED		MARITIME MOBILE	MARITIME MOBILE MOBILE Radiolocation	FIXED     MARITIME MOBILE     TO LOOP All the state       Radiolocation     Aeronautical Mobile
	MARITIME MOBILE	STANDARD FREG. A	FIXED	THE STATE ST	MARITIME MOBILE FIXED AERONAUTICAL MOBILE
3 kHz					
300 325 325 335 405 415 435 435 505	52 P 23 C			1605	1800 1900 2107 2107 2130.5 2194 2134 2501 2505 2505
Aeronautical Radionavigation (Radio Beacons)		BROADCASTING		PILISYODHOUR DILLEX	Areura Materia Mate
MARITIME RADIO/NAVIGATION (RADIO BEACONS) WOBILE MUSIC RADIO WOULD A MODILE MUSIC MUSIC MODILE MUSIC MODILE	(SHIPS ONLY)			HI HIGH CATION	
300 kHz				TRAVELERS INFORMATION STATIONS (G) AT 1610 kHz	
3.005 3.155 3.155 3.155 3.230 3.4 3.5 3.5 4.65 4.453 4.453 4.455 4.455 4.455 4.455 4.455 4.455 4.455 4.455 4.455 4.455 5.002 5.0000 5.0020	5.050 5.45 5.768 5.768 6.525 6.255 6.255 6.255 6.255 6.255 7.0	8, 7, 35 8, 1, 35 8, 1, 195 9, 9, 6, 6 9, 9, 6 1, 6 1, 7, 35 7, 35	10.003 10.005 10.005 10.005 10.005 10.005 10.005 11.75 11.75 11.75 11.75 11.75 11.75 11.75 11.75 11.25 12.23 12.23 12.23 13.26 14.26	13.57 13.67 13.8 13.8 14.28 14.28 14.290 14.205 15.005 15.	18.78 19.08 19.09 19.09 19.09 20.010 20.000 20.000 20.000 20.000 20.000 20.0000 20.0000 20.0000 20.0000 20.0000 20.0000 20.0000 20.0000 20.0000 20.0000 20.0000 20.0000 20.0000 20.0000 20.0000 20.0000 20.00000 20.00000 20.00000000
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9:0:	0722 BROADCASTING (TV CHANNELS 2-4)	0'88 0'88 0'82 0'82 0'92	108.0 AERONAUTICAL MOBILE (R) AERONAUTICAL MOBILE (R) AERONAUTICAL MOBILE (R) AERONAUTICAL MOBILE (R) 123.8 123.8 123.0 123	ACTOVATIONAL MOBILE (1) ACTOVA	BROADCASTING (TV CHANNELS 7-13) BROADCASTING (TV CHANNELS 7-13) BROADCASTING (TV CHANNELS 7-13) BROADCASTING (TV CHANNELS 7-13) BROADCASTING BROADCASTING (TV CHANNELS 7-13) BROADCASTING B
300.00 322.0 322.5 335.4 335.4 400.05 400.15 400.05 400.05 400.0 400.0 400.0 400.0 400.0 400.0 400.0 400.0 400.0 425.0 400.0 425.0 45.0 45.0 45.0 45.0 45.0 45.0 45.0 4	608.0 614.0 638 745 745	794 8221 8224 8249 8655 9940 9322 9410 9411 9410 9410 9411 9410 9410 9410	1215 1215 1300 1390 1395 1395 1395 1395 1395 1420 1420 1420	1432 1435 1526 1544 1544 1546 1549.5 1559.5 1559.5 1559.5 1559.5 1650.5 1670.6 1670.6 1660.5 1660.5 1660.5 1660.5 1660.5 1670.6 1700.6	1755 1755 2000 2000 2000 2000 2155 2155 2110 22200 21550 23305 23305 23305 23305 23305 23305 23305 23305 23305 23305 23305 23305 23305 23305 23305 23365 2356 2356
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r r r r r r r r r r r r r r r r r r r	ABERONNUTION.     ABERONNUTION.       AFEND FROMUTION.     ARENONNUTION.       AFEND FROMUTION.     FIXED SATIES       ADDIOLOCATION     Radiologiton       ABERONNUTION.     Radiologiton       ABERONNUTION.     Radiologiton       ABERONNUTION.     Radiologiton       ABERONNUTION.     Radiologiton       ADDIOLOCATION     Radiologiton       ADDIOLOCATION     Radiologiton       Antratar     Antratar       ANTRUE     Antratar       ANDIE     Antratar       ANDIE     Antratar </th <th>REDSINILINE ELE     FRED     Music state anti-fields     Fred       Surfure[ss]     Surfure[ss]     Fred     7.       Surfure[ss]     Fred     Surfure[ss]     Fred       Surfure[ss]     Fred     Surfure[ss]     Fred       Surfure[ss]     Fred     Surfure[ss]     Fred       Surfure[ss]     Surfure[ss]     Fred     Surfure[ss]       Surfure[ss]     Surfure[ss]     Fred     Suffure[ss]       Suffure[ss]     Suffure[ss]     Fred     Suffure[ss]       Suffure[ss]     Suffure[ss]     Suffure[ss]     Suffure[ss]</th> <th>Actionation and a series and a</th> <th>SERONUTICAL RELORM     Stores fressart [5], [1], [2], [2], [2], [2], [2], [2], [2], [2</th> <th>FIXED     ATTRLIFTE     (S.E.)     ATTRLIFTE     (S.E.)       FIXED     SATELLIFE     (S.E.)     ATTRLIFTE     (S.E.)       FIXED     SATELLIFE     (S.E.)     ATTRLIFTE     (S.E.)       FIXED     SATELLIFE     (S.E.)     ATTRLIFTE     (S.E.)       SPACE     FIXED     MOBILE     FIXED     MOBILE     FIXED       FIXED     MOBILE     FIXED     MOBILE     FIXED     MOBILE       FIXED     MOBILE     FIXED     MOBILE     FIXED     MOBILE</th>	REDSINILINE ELE     FRED     Music state anti-fields     Fred       Surfure[ss]     Surfure[ss]     Fred     7.       Surfure[ss]     Fred     Surfure[ss]     Fred       Surfure[ss]     Fred     Surfure[ss]     Fred       Surfure[ss]     Fred     Surfure[ss]     Fred       Surfure[ss]     Surfure[ss]     Fred     Surfure[ss]       Surfure[ss]     Surfure[ss]     Fred     Suffure[ss]       Suffure[ss]     Suffure[ss]     Fred     Suffure[ss]       Suffure[ss]     Suffure[ss]     Suffure[ss]     Suffure[ss]	Actionation and a series and a	SERONUTICAL RELORM     Stores fressart [5], [1], [2], [2], [2], [2], [2], [2], [2], [2	FIXED     ATTRLIFTE     (S.E.)     ATTRLIFTE     (S.E.)       FIXED     SATELLIFE     (S.E.)     ATTRLIFTE     (S.E.)       FIXED     SATELLIFE     (S.E.)     ATTRLIFTE     (S.E.)       FIXED     SATELLIFE     (S.E.)     ATTRLIFTE     (S.E.)       SPACE     FIXED     MOBILE     FIXED     MOBILE     FIXED       FIXED     MOBILE     FIXED     MOBILE     FIXED     MOBILE
200 Control of the second of	Provide	Andreue     Andreue     Andreue     74.0       Satellite(Ee.S)     FaceD     Andreue     75.5       Satellite(Ee.S)     FaceD     Andreue     75.5       Bablootocc     Andreue     Andreue     77.5       Bablootocc     Andreue     Andreue     77.5       Bablootocc     Andreue     Andreue     77.5       Bablootocc     Andreue     Andreue     77.5       FaceDicoc     Andreue     Andreue     77.5       FaceDicoc     Andreue     Andreue     77.5       FaceDicoc     Andreue     Andreue     8.0       FaceDicoc     Andreue     Andreue     8.0       FaceDicoc     Andreue     Andreue     8.0       FaceDicoc     Andreue     Andreue     8.0       FaceDicoc     Andreue     8.0     8.0       FaceDico     Andreue     8.0     8.0       FaceDico <th>0001 USUBLE PARTIE PART</th> <th>134.0     134.0       134.0</th> <th>15000000000000000000000000000000000000</th>	0001 USUBLE PARTIE PART	134.0     134.0       134.0	15000000000000000000000000000000000000

![](_page_18_Figure_6.jpeg)

![](_page_19_Figure_0.jpeg)

![](_page_19_Figure_1.jpeg)

![](_page_19_Figure_2.jpeg)

54.0

	1605 1615	1705	
	IOADCASTING		FIXE
BROADCASTING (AM RADIO)		BROADCASTING	MOBI
	MOBILE		RADI LOCAT
TRAVELERS INFORM.	ATION STA	ATIONS (G) A	T 1610

6.2	6.525	6.765	7.1	7.3	7.35		8.1 8.195		8.815 8.965	9.040 9.4	9.5	9.9 9.995 10.003 10.005 10.1	10.15	11.175	11.275 11.4 11.6 11.65	12.05	12.10	13.2	13.26 13.36 13.41	13.57 13.6	13.87 13.87 14.0 14.25	14.35	15.005 15.010 15.010	15.6	15.8	16.36	17.41 17.48 17.55	17.9 17.97 18.03 18.068
MOBILE	L MOBILE (R)	MOBILE (OR)	AMATEURSATELLITE	EUR	BROADCASTING	FIXED	MARITIME MOBILE	MARITIME	L MOBILE (R) MOBILE (D)	ED	BHOADCASTING ASTING	ED ME SIGNAL (10,000kHz) Space Research LunoBILE (R)	FIXE	ED	L MOBILE (B) D BROADCASTING	ASTING BROADCASTING		IME LE Wore for	LI MOBLE (R) RONDAN	TING Mobile*	TNS Mobile* AMATEURSATELLITE	Mobile*	ME S/GNAL (15,000 kHz) Space Research MOBILE (OR)	ASTING	BIDADCASTING	TIME	EFDADCASTING ASTING	L MOBILE (R) . MOBILE (OR) ED AMATELIR
MARITIME	AERONAUTICA	AERONAUTICAL Mobile	AMATEUR	AMAT	Mobile	Mobile	FIXED	MOBILE	AERONAU TI CA AFRONALITICA	EIXI	BROADC	FIXE STANDARD FREQ. AND TH STANDARD FREQ. AND TH AEPONAUTICA	Mob	ile*	AERONAUTICA	BROADC	BXH	MARIT MOBI	AERONAUTICA	FIXED BROADCAS BROADCAS BROADCA	FIXED BECADOAS FIXED AMATEUR	FIXED	STANDARD FREQ. AND TI STANDARD FREQ. AERONAUTICAL	BROADC		MARI	FIXE FIXED BROADC	AERONAUTICA AERONAUTICAL FIXE AMATELIE SATELLITE
-	_	ISM - 6.78	±.015 M	Hz						_									ISM - 13	.560 ± .0	07 MHz					_		
				72.0	73.0 74.6	74.8 75.2 75.4 76.0			88.0					0.901		117.975	121.9375 123.0875 123.5875		128.8125 132.0125	136.0	137.025 137.175 137.825 138.0	144.0 146.0	150.05 150.05	152.855	156.2475 157.0375 157.1875	157.45 161.575 161.625 161.775	162.0125	173.2 173.4
	NG			MOBILE		MOBILE MOBILE MOBILE	BRO				BROADO			AERO		- UTICAL E (R)	AL MOBILE	UTICAL E (R)	UTICAL E (R)	l mobile (r) L mobile (r)	SPACE CPN (SE) INT SM (SE) SPACE CPN (SE) INT SM (SE) SPACE CPN (SE) INT SM (SE) SPACE CPN (SE) INT SM (SE)	MOBILE AMATEUR SATELLITE	ED MOBILE Mobile Sateluite (ES) Mobile	JBILE	LAND MOBILE MOBILE MOBILE	LAND MOBILE LAND MOBILE MOBILE BILE		Land Motitle MOBILE
V CHANNELS	o 2-4)			FIXED	RADIO AST	AERONAUTICAL RA FIXED FIXED		TAININELS 5-0)			( FIVI FI			RADION	AVIGATION	AERONA MOBIL	AERONAUTIC	AERONAI MOBILI	AERONA	AERONAUTICA AERONAUTICA	NGB SAT. (SE) SPACERES (SE) NALS S# (SE) SPACERES (SE) NGB SAT. (SE) SPACERES (SE) NALS S# (SE) SPACERES (SE)	FIXED AMATEUR AMAT	RADIONAV-SATELLITE FKED	FKED LAND MC	FIXED MARITME MARITIME	MARITIME MOBILE FIXED MARITIME LANDING	MANUME MOBILE	EXED CI

![](_page_19_Picture_92.jpeg)

	161	04
E MOBILE AERONAUTE BROADCASTING	BROADCASTING	STING
(AM RADIO) WARITIME MARITIME (SHIPS ONLY) MOBILE	MOBILE	BROADCA

![](_page_20_Figure_1.jpeg)

ISM - 6.78 ± .015 MHz

![](_page_20_Figure_3.jpeg)

TRAVELERS INFORMATION STATIONS (G) AT 1610 kHz

ISM – 13.560 ± .007 MHz

	108.0	117.975	121.9375 123.0875 123.5875	128.8125	132.0125	136.0 137.0 137.175 137.175 137.825 138.0	144.0 146.0 149.0 150.05	150.8 152.855	154.0 156.2475	157.0375 157.1875 157.45	161.625	161.775 162.0125	
BROADCASTING	AERONAUTICAL	UTICAL	e (rt) : <u>XL MOBILE</u> : <u>XL MOBILE</u> UTICAL = (R)	UTICAL	e (H) L Mobile (R)	PAGE CPN. (SE) SPACE CPN. (SE) SPACE CPN. (SE) SPACE CPN. (SE) SPACE CPN. (SE) MET.SAT. (SE) SPACE CPN. (SE) MET.SAT. (SE)	MOBILE AMATEUR SATELLITE EUR MOBILE SATELLITE (E-S)	MUBILE LAND MOBILE DBILE	LAND MOBILE MOBILE	MOBILE LAN D MOBILE LAND MOBILE	MOBILE	LAND MOBILE	MOE
	RADIONAVIGATION	AERONA	AERONAUTIC AERONAUTIC AERONAL	AERONAL		AERONAUTICA MOB.SAT.(SE) SPACERES.(SE) Mob.Sat.(SE) SPACERES.(SE) MOB.SAT.(SE) SPACERES.(SE) MOB.SAT.(SE) SPACERES.(SE) Mob.Sat.(SE) SPACERES.(SE)	HIXED AMATEUR AMAT MATEUR AMAT MATELLITE	FIXED FIXED LAND MC	FIXED MARITIME	MARITIME MARITIME MOBILE FIVED	MA RI TIME LANDING	MARITIME MOBILE	FIX

![](_page_20_Picture_7.jpeg)

![](_page_20_Picture_9.jpeg)

![](_page_20_Picture_10.jpeg)

s f	G	<u>WITH</u>	90.1 FM	10.0 mi.🕋	Ithaca, NY		Public Radio
	<b>(i</b> )	<u>WSQG</u>	90.9 FM	10.0 mi.🕋	Ithaca, NY		Public Radio
	€	WICB	91.7 FM	1.8 mi.≃	Ithaca, NY	Ithaca College	College
	€	W221CW (WSQG)	92.1 FM	10.0 mi.🕋	Ithaca, NY		Public Radio
	€	<u>WVBR</u>	93.5 FM	2.7 mi.🕿	Ithaca, NY		Rock
	€	W231DK (WNYY-AM)	94.1 FM	3.8 mi.≃	Ithaca, NY		Oldies
	€	<u>W235BR (WQNY)</u>	94.9 FM	3.8 mi.≃	Ithaca, NY		Country
	€	<u>WFIZ</u>	95.5 FM	9.5 mi.🕋	Odessa, NY		Top-40
	€	<u>W240CB (WQNY)</u>	95.9 FM	3.8 mi.🕿	Ithaca, NY		Country
	€	<u>W242AB (WYXL)</u>	96.3 FM	3.8 mi.🕿	Ithaca, NY		Adult Contempora
	€	<u>W244CZ (WYXL)</u>	96.7 FM	3.8 mi.≃	Ithaca, NY		Adult Contempora
	ⓐ	<u>WYXL</u>	97.3 FM	6.6 mi.🕿	Ithaca, NY		Adult Contempora
	€	<u>WIII</u>	99.9 FM	19.2 mi.🕋	Cortland, NY		Classic Rock
	٤	<u>W262AD (WIII)</u>	100.3 FM	3.8 mi.≃	Ithaca, NY		Classic Rock
Ż	٤	<u>W269AW</u> (WMHR)	101.7 FM	2.1 mi.	Ithaca, NY		Religious
Ż	<b>i</b>	<u>W272DY (WZXV</u> )	102.3 FM	2.7 mi.	East Ithaca, NY		Religious
	<b>(i)</b>	<u>W277BS (WQNY)</u>	103.3 FM	3.8 mi.🕋	Ithaca, NY		Country
	<b>(i)</b>	<u>WQNY</u>	103.7 FM	9.5 mi.🕋	Ithaca, NY		Country
Ż	<b>(i</b> )	<u>W283BQ (WRVO)</u>	104.5 FM	4.1 mi.🕋	Ithaca, NY	State University of	Public Radio

![](_page_21_Picture_1.jpeg)

![](_page_22_Figure_0.jpeg)

#### We found 2 vacant channels on the FM dial in Ithaca, New York.

The graph above shows the predicted interference from other stations at each frequency on the FM dial. Red indicates strong interference, green indicates a weak interference.

Vacant Channels	Next Best Channels	Third Best Channels
101.1 FM BEST! 106.5 FM BEST!	89.7 FM GREAT	92.9 FM GOOD 97.7 FM GOOD 98.9 FM GOOD 100.7 FM GOOD 102.7 FM GOOD 106.3 FM GOOD

Attention: Before transmitting on an FM frequency, always check to see if the channel is truly vacant by listening with an FM radio. Your audio device will work best on an empty channel and you will be less likely to cause interference with other people's radio reception.

![](_page_22_Picture_5.jpeg)

![](_page_22_Picture_6.jpeg)

![](_page_23_Picture_0.jpeg)

#### SHANNON-HARTLEY THEOREM

## $C = B \log_2 (1+S/N)$

![](_page_24_Picture_4.jpeg)

### SHANNON-HARTLEY THEORFM

#### bandwidth of the channel

Channel capacity in bits/s

# $C = B \log_2 (1+S/N)$ signal-to-noise ratio

![](_page_25_Picture_5.jpeg)

## SHANNON-HARTLEY THEOREM

#### bandwidth of the channel

Channel capacity in bits/s

![](_page_26_Figure_4.jpeg)

![](_page_26_Picture_5.jpeg)

#### SHANNON LIMIT

![](_page_27_Figure_1.jpeg)

Example: Optical fiber channel linking US and China

![](_page_27_Picture_3.jpeg)

## RADIO SUMMARY

- ► Analog radio
- ► Your radios use a digital protocol!
- ► Abstraction...

![](_page_28_Picture_5.jpeg)

# LAB 4

![](_page_29_Picture_2.jpeg)

![](_page_30_Picture_0.jpeg)

## NORDIC NRF24L01+

- Packet-based communication
- ► Enhanced ShockBurst<sup>™</sup>
- ► Radio runs on 3.3V!

![](_page_30_Picture_5.jpeg)

![](_page_31_Picture_0.jpeg)

### NORDIC NRF24L01+

- Packet-based communication
- ► Enhanced ShockBurst<sup>™</sup>

► Radio runs on <u>3.3V</u>!

![](_page_31_Picture_5.jpeg)

# 3.3 VOLTS

![](_page_32_Picture_2.jpeg)

![](_page_33_Picture_0.jpeg)

![](_page_33_Picture_12.jpeg)

![](_page_33_Picture_15.jpeg)

![](_page_34_Picture_0.jpeg)

![](_page_35_Picture_0.jpeg)

## NORDIC NRF24L01+

- Packet-based communication
- ► Enhanced ShockBurst<sup>™</sup>
- ► Radio runs on 3.3V!

![](_page_35_Picture_5.jpeg)

![](_page_36_Picture_0.jpeg)

#### **Enhanced ShockBurst**<sup>™</sup>

Enhanced ShockBurst<sup>™</sup> is a packet based data link layer. It features automatic packet assembly and timing, automatic acknowledgement and re-transmissions of packets. Enhanced ShockBurst<sup>™</sup> enables the implementation of ultra low power, high performance communication with low cost host microcontrollers. The features enable significant improvements of power efficiency for bi-directional and uni-directional systems, without adding complexity on the host controller side.

#### nRF24L01 Product Specification

![](_page_36_Figure_4.jpeg)

![](_page_36_Picture_5.jpeg)

![](_page_37_Figure_0.jpeg)

![](_page_37_Picture_1.jpeg)

Layers of Abstraction

![](_page_37_Picture_3.jpeg)

![](_page_38_Picture_0.jpeg)

![](_page_38_Picture_1.jpeg)

![](_page_38_Picture_2.jpeg)

![](_page_38_Picture_3.jpeg)

![](_page_38_Picture_4.jpeg)

![](_page_38_Picture_5.jpeg)

![](_page_38_Picture_6.jpeg)

HARDWARE

#### SOFTWARE

![](_page_38_Figure_11.jpeg)

![](_page_38_Figure_12.jpeg)

![](_page_38_Figure_13.jpeg)

![](_page_38_Figure_14.jpeg)

![](_page_38_Picture_15.jpeg)

Physical

![](_page_39_Figure_0.jpeg)

## OSI MODEL

- Open Systems Interconnection model
- Abstraction hierarchy for networks

![](_page_40_Figure_0.jpeg)

## OSI MODEL

Open Systems Interconnection model

Abstraction hierarchy for networks

Protocol (Enhanced ShockBurst<sup>TM</sup>)

![](_page_40_Picture_5.jpeg)

![](_page_40_Picture_6.jpeg)

## $ENHANCED\ SHOCKBURST^{\mathsf{TM}}$

- Packet-based
- ► Handles retries
- ► Handles ACKs

![](_page_41_Picture_4.jpeg)

![](_page_42_Figure_0.jpeg)

## OSI MODEL

Open Systems Interconnection model

Abstraction hierarchy for networks

Protocol (Enhanced ShockBurst<sup>TM</sup>)

![](_page_42_Picture_5.jpeg)

![](_page_43_Figure_0.jpeg)

### OSI MODEL

Open Systems Interconnection model

Abstraction hierarchy for networks

![](_page_43_Picture_4.jpeg)

Protocol (Enhanced ShockBurst<sup>TM</sup>)

![](_page_43_Picture_6.jpeg)

![](_page_43_Picture_7.jpeg)

Preamble 1 byte	Address 3-5 byte	Packet Control Field 9 bit	Payload 0 - 32 byte	CRC by
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#### Figure 4. An Enhanced ShockBurst<sup>™</sup> packet with payload (0-32 bytes)

![](_page_44_Picture_2.jpeg)

![](_page_44_Picture_3.jpeg)

Preamble 1 byte	Address 3-5 byte	Packet Control Fie

![](_page_45_Figure_2.jpeg)

47

Figure 4. An Enhanced ShockBurst<sup>™</sup> packet with payload (0-32 bytes)

Payload length 6bit

#### Figure 5. Packet control field

![](_page_46_Picture_3.jpeg)

![](_page_46_Picture_4.jpeg)

# ALL OF THIS IS DONE FOR YOU! YOUR LIFE MADE EASY (BY ABSTRACTION)

![](_page_47_Picture_1.jpeg)

![](_page_48_Figure_0.jpeg)

![](_page_48_Picture_2.jpeg)

![](_page_49_Figure_0.jpeg)

![](_page_49_Picture_4.jpeg)

- Abstraction.jpg
- Claude Shannon video: https://www.youtube.com/watch?v=vPKkXibQXGA
- Frequency Modulation video: https://www.youtube.com/watch?v=gfz1FbIOMbs
- Radio stations in Ithaca: https://radio-locator.com/cgibin/locate?select=city&city=lthaca&state=NY&band=Both&dx=0&sort=freq
- ► Shannon-Hartley Figure: https://electronics.stackexchange.com/questions/234735/maximum-bit-rate-of-a-noiseless-channel
- limits-facing-optical-networking.html

Abstraction image: http://theembeddedguy.com/wp-content/uploads/2016/05/Layers-of-

Shannon Limit Figure: <u>http://www.gazettabyte.com/home/2012/5/15/the-capacity-</u>

Sol Model: https://maidsafeplatform.files.wordpress.com/2015/02/maid-osi.png

![](_page_50_Picture_10.jpeg)