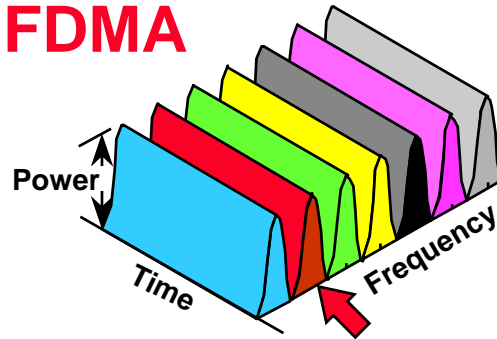


Chapter 3

Wireless Systems: Multiple Access Technologies & Standards

Multiple Access Methods

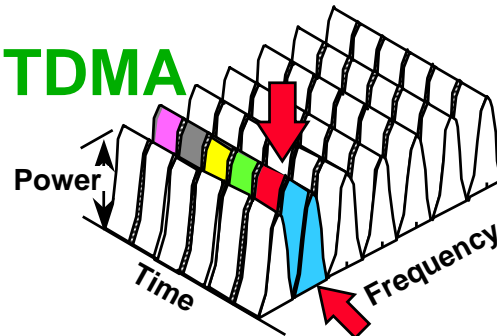
FDMA



FDMA: AMPS & NAMPS

- Each user occupies a private Frequency, protected from interference through physical separation from other users on the same frequency

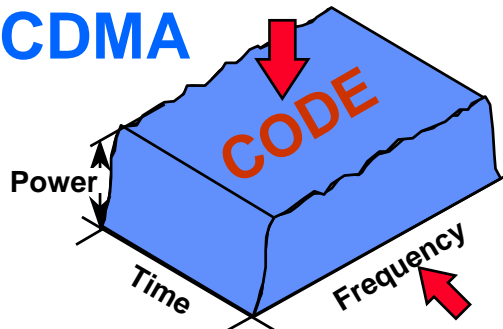
TDMA



TDMA: IS-136, GSM

- Each user occupies a specific frequency but only during an assigned time slot. The frequency is used by other users during other time slots.

CDMA



CDMA

- Each user occupies a signal on a particular frequency simultaneously with many other users, but is uniquely distinguishable by correlation with a special code used only by this user

The CDMA Technology Path to 3G

		CDMAone		CDMA2000/IS-2000		
Generation	1G	2G	2G	2.5G or 3?	3G	3G
Technology	AMPS	IS-95A/J-Std008	IS-95B	IS-2000: 1xRTT	IS-2000: 3xRTT	1xEV: HDR or 1Xtreme
Signal Bandwidth, #Users	30 kHz. 1	1250 kHz. 20-35	1250 kHz. 25-40	1250 kHz. 50-80 voice and data	F: 3x 1250k R: 3687k 120-210 per 3 carriers	1250 kHz. Many packet users
Data Capabilities	None, 2.4K by modem	14.4K	64K	153K 307K 230K	1.0 Mb/s	2.4 Mb/s (HDR) 5 Mb/s (1Xtreme)
Features: Incremental Progress	First System, Capacity & Handoffs	First CDMA, Capacity, Quality	<ul style="list-style-type: none"> •Improved Access •Smarter Handoffs 	<ul style="list-style-type: none"> •Enhanced Access •Channel Structure 	Faster data rates on shared 3-carrier bundle	Faster data rates on dedicated 1x RF data carrier

The GSM Technology Path to 3G

Generation	1G	2G	2.5G or 3?	3G	3G
Technology	various analog	GSM	GPRS	EDGE	UMTS UTRA WCDMA
Signal Bandwidth, #Users	various	200 kHz. 7.5 avg.	200 kHz. Many Pkt. users	200 kHz. fast data many users	3.84 MHz. up to 200+ voice users and data
Data Capabilities	various	none	9-160 Kb/s (conditions determine)	384 Kb/s mobile user	2Mb/s static user
Features: Incremental Progress	various	Europe's first Digital wireless	<ul style="list-style-type: none"> •Packet IP access •Multiple attached users 	Faster data rates on dedicated 200 kHz data carrier	Integrated voice and data

The TDMA IS-136 Technology Path to 3G

Generation	1G	2G	2G	2G	2.5G or 3?	3G	3G
Technology	AMPS	CDPD	TDMA IS-54 IS-136	GSM	GPRS	EDGE	UMTS UTRA WCDMA
Signal Bandwidth, #Users	30 kHz. 1	30 kHz. Many Pkt Usrs	30 kHz. 3 users	200 kHz. 7.5 avg.	200 kHz. Many Pkt. users	200 kHz. fast data many users	3.84 MHz. up to 200+ voice users and data
Data Capabilities	None, 2.4K by modem	19.2 kbps	none	none	9-160 Kb/s (conditions determine)	384 Kb/s mobile user	2Mb/s static user
Features: Incremental Progress	First System, Capacity & Handoffs	US Packet Data Svc.	USA's first Digital wireless	Europe's first Digital wireless	<ul style="list-style-type: none"> •Packet IP access •Multiple attached users 	Faster data rates on dedicated 200 kHz data carrier	Integrated voice and data

Wideband LAN (WiLAN) Technologies

Technology	Infrared IRDA	Bluetooth	802.11b	802.11a	HIPERLAN Type 1	HIPERLAN Type 2
Frequency Band	Optical	2.4 GHz	2.4 GHz	5 GHz	5 GHz	5 GHz
Access Method	Single User per Optical Carrier	various	DSSS	DSSS	OFDM	3.84 MHz.
Modulation Type	various	GFSK FH	CCK	BPSK, QPSK, 16QAM, or 64QAM	FSK or GMSK	BPSK, QPSK, 16QAM, or 64QAM
Max Raw Data Rate	4 Mb/s	1 Mb/s	11 Mb/s	54 Mb/s	23.5 Mb/s	54 Mb/s



Survey of Analog Wireless Technologies

	AMPS IS553	NAMPS IS-91	TACS	NMT450	NMT900	C-450
Frequency Band	800	800	900	450	900	450
Channel Spacing	30 kHz.	10 kHz.	25	25	12.5	20
Speech Modulation	FM	FM	FM	FM	FM	FM
Freq. Deviation	12 kHz.	5 kHz.	9.5	5.0	5.0	4.0
Signalling Modulation	Dir.FSK	Dir.FSK	Dir.FSK	Aud.FFSK	Aud.FFSK	Dir.FSK
Signalling Bit Rate	10 kb/s	10 kb/s	8 kb/s	1200 b/s	1200 b/s	5280 b/s
Overlay Signalling?	no	no	no	no	no	yes
Paging/Access	CCH (f)	CCH (f)	CCH (f)	CCH (f)	CCH (f)	CCH (f)
In-Call Supervision	SAT	DSAT	SAT	?	?	overlay
In-Call Control	ST	DSAT	ST	?	?	overlay
Call Control	ST	DSAT	ST	?	?	overlay
Handoff Logic	BTSLCR	BTSLCR	BTSLCR	BTSLCR	BTSLCR	BTSLCR

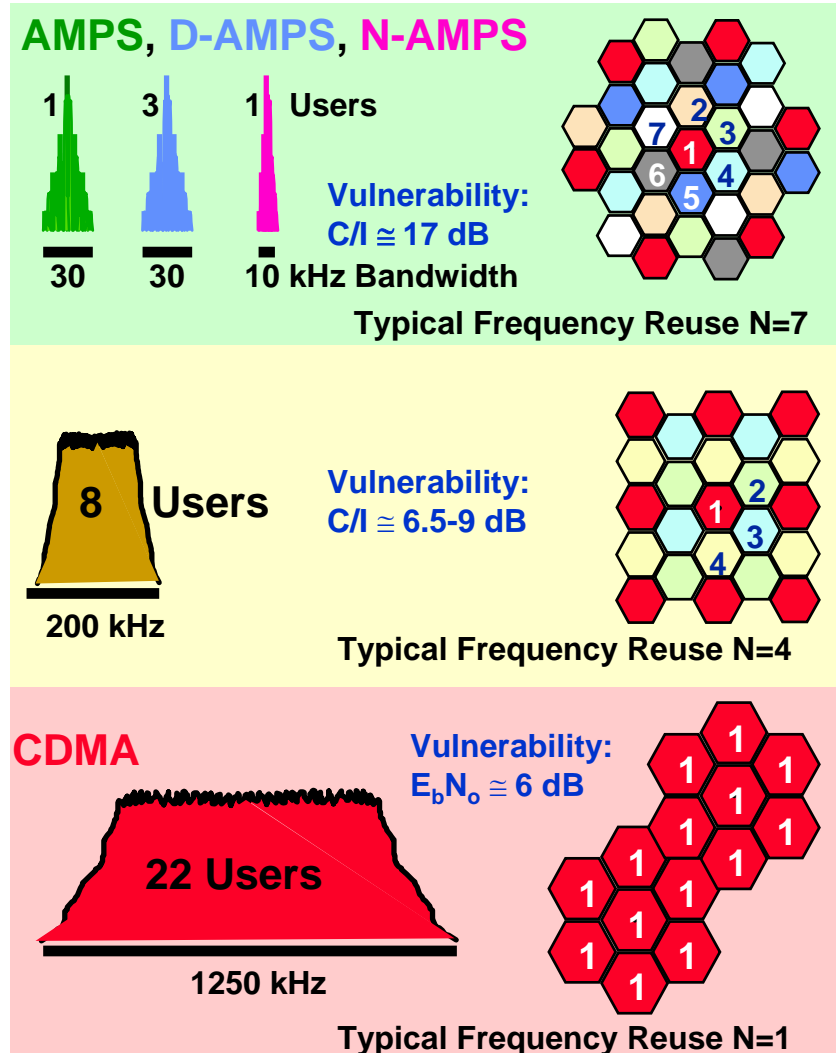
Survey of Digital Wireless Technologies

	GSM, DCS1800 PCS1900	D-AMPS <i>IS-54</i> <i>IS-136</i>	CDMA <i>IS-95</i> <i>JStd008</i>	Japan PDC	CT-2	DECT
Access Method	TDMA	TDMA	CDMA	TDMA	TDMA	TDMA
Frequency Band(s)	900 1800 1900	800 1900*	800 1900	8/900 1400	865	1880
Channel Spacing	200	30, 50*	x	50/25i	100	1728
Modulation type	GMSK	DQPSK	QPSK	DQPSK	GFSK	GFSK
Signal Bandwidth	200+	30	1250+	50	100	1800
Signalling Modulation	GMSK	DQPSK	QPSK	DQPSK	GFSK	GFSK
Transmission, kb/s	~240	~44	1229ss	42	72	1152
Paging/Access ch.	CCH (t)	CCH(f)	CCH(c)	CCH(f)	BCH	BCH
Signalling kb/s	~30	~44	9.6	x	32	32
Info kb/s	14.4	x	9.6,14.4	11.2	32	32
Info frames/s	~200	50	50	50	packets	100
In-Call signalling	TCH, SDCCH	TCH, SACCH	TCH	ACCH SACCH	hybrid	hybrid
Handoff Logic	MAHO	MAHO+	MDHO	?	?	MDHO

Spectrum Usage Capacity Considerations: Signal Bandwidth, C/I and Frequency Reuse

Each wireless technology (AMPS, NAMPS, D-AMPS, GSM, CDMA) uses a specific modulation type with its own unique signal characteristics

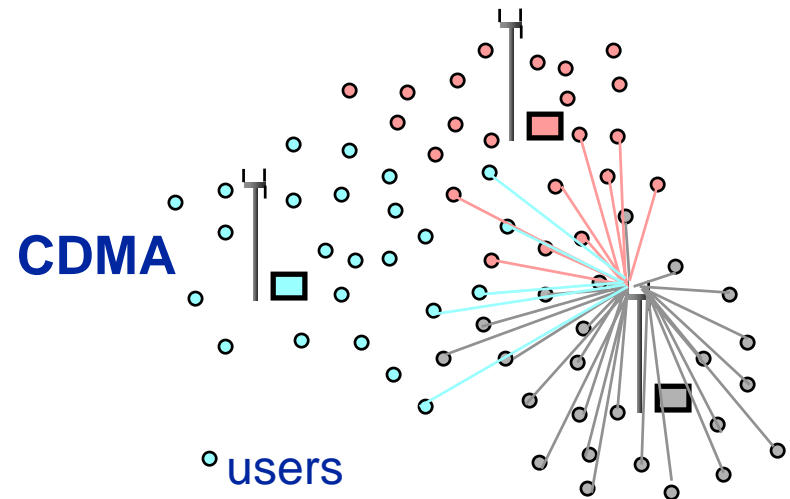
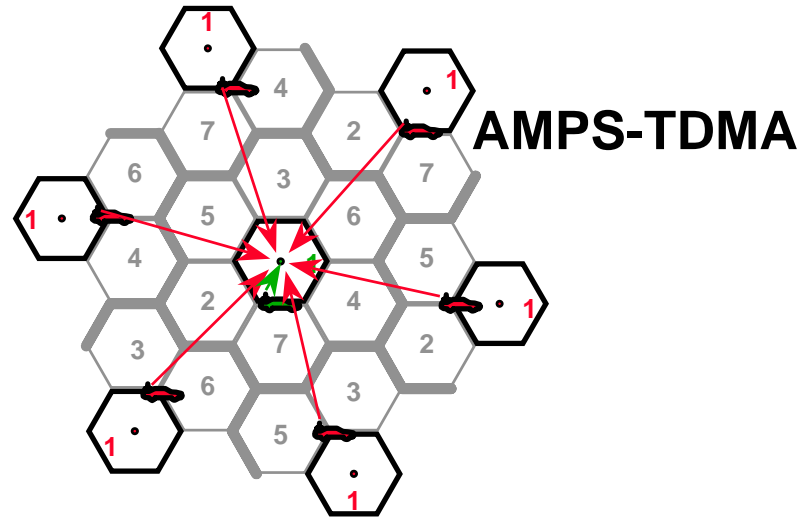
- Signal Bandwidth determines how many RF signals will “fit” in the operator’s licensed spectrum
- Robustness of RF signal determines tolerable level of interference and necessary physical separation of cochannel cells
- Number of users per RF signal directly affects capacity



Interference From Where?




















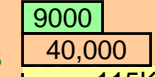






FDMA vs CDMA Uplink Example

- AMPS, N-AMPS, TDMA, and GSM systems use FDMA and separate same-frequency users into cells physically far apart to achieve required C/I values
- CDMA systems allow all users in all cells/sectors to use the same frequency. Thus, each nearby user is a source of interfering energy against all other users, and a user's raw C/I is actually negative. Each user is recovered with its own unique code, the processing gain elevating that user above the demodulated noise floor

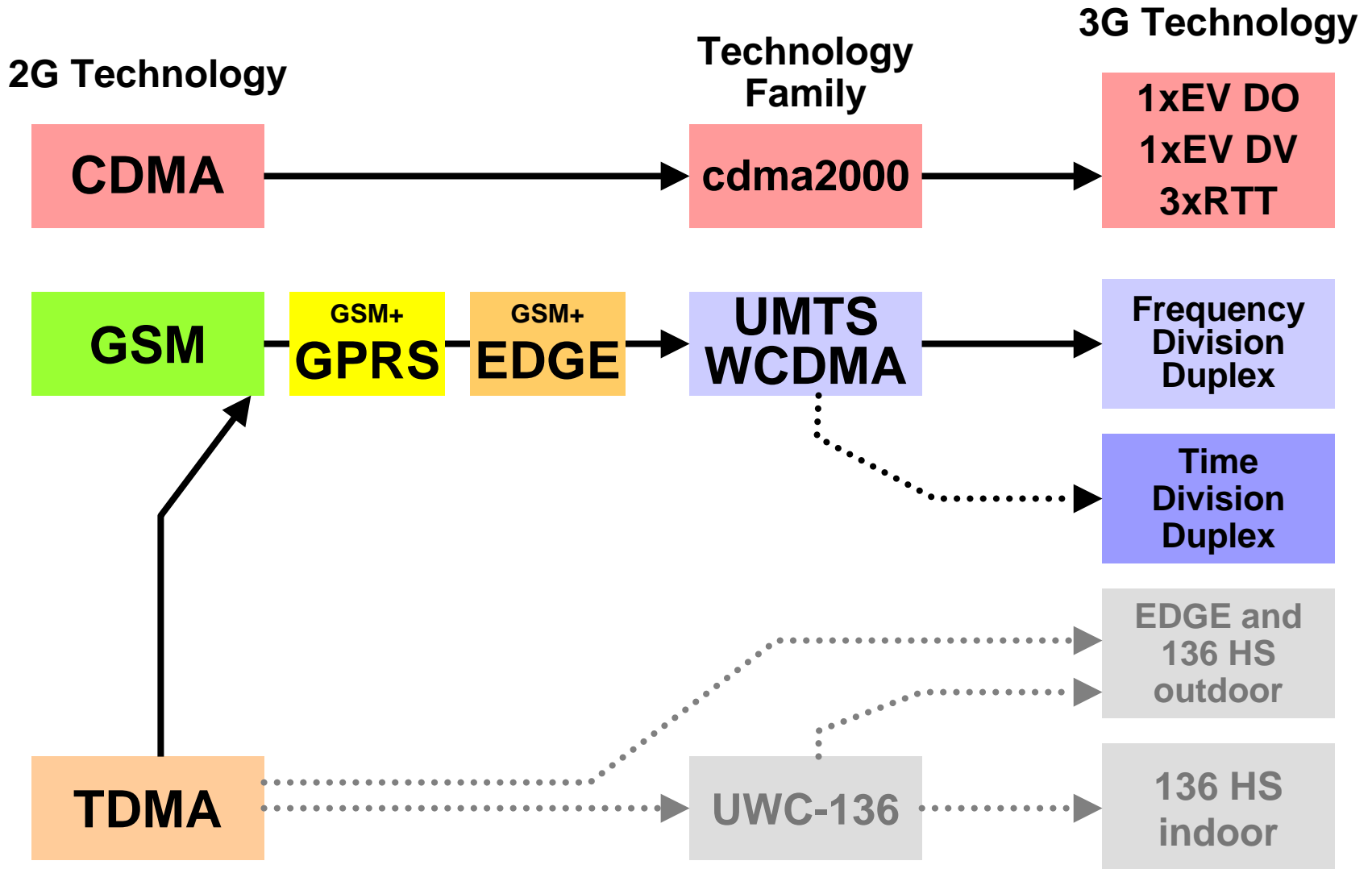


Survey of Wireless Data Technologies

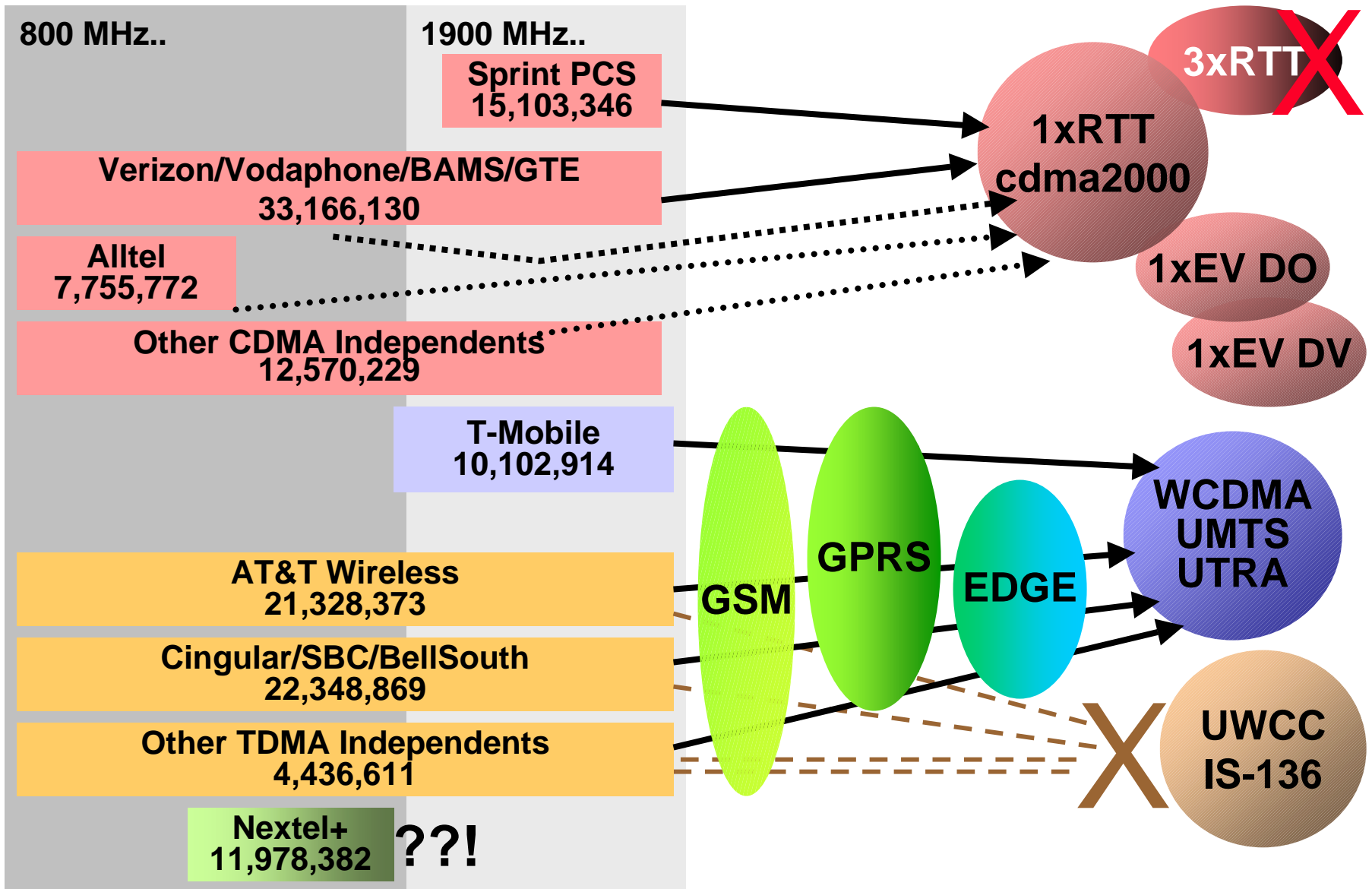
- Each wireless technology offers some data capability today
- One or more circuit-switched traffic channels may be assigned for fast data instead of voice
 - Dial-up modem emulation is provided at the wireless switch
 - Packet data access may be provided by a router at the switch, but the RF link is circuit-switched
 - Data rates are slow; compression may be provided
- Even 2G CDPD and Mobitex Data-Only technologies are slow!
- 3G technologies are much better!
 - Much faster RF traffic channels
 - True packet-switched channel management

AMPS	 Circuit Switched		9600 14400	2G
TDMA IS-136	 Circuit Switched		9600	
GSM	 Circuit Switched		9600 14400	
IDEN	 Circuit Switched		19200	
CDMA IS-95	 Circuit Switched		9600 14400 [64K]	
CDPD	 IP Packets		19200	 
Mobitex	 IP Packets		9600 Shared	 
GPRS, EDGE	 IP Packets		9000 40,000 115K	18000 120,000 384k 2.5G
CDMA2000 1xRTT	 IP Packets		153K 230K 307K	
CDMA2000 1xEV	 IP Packets		2.4 M	3G
WCDMA UMTS	 IP Packets		1M 2M	

2G to 3G Migration Paths



North American Operators' Technology Paths



4G: Broadband Wireless Access Technologies

Technology	Infrared IRDA	Bluetooth	802.11b	802.11a	HIPERLAN Type 1	HIPERLAN Type 2	802.16	802.20 Mobile BWA
Frequency Band	Optical	2.4 GHz	2.4 GHz	5 GHz	5 GHz	5 GHz	2-11 GHz 10-66 GHz	
Access Method	Single User per Optical Carrier	various	DSSS	DSSS	OFDM	various.	TDD, FDD various	
Modulation Type	various	GFSK FH	CCK	BPSK, QPSK, 16QAM, or 64QAM	FSK or GMSK	BPSK, QPSK, 16QAM, or 64QAM	BPSK to 256QAM OFDM	
Max Raw Data Rate	4 Mb/s	1 Mb/s	11 Mb/s	54 Mb/s	23.5 Mb/s	54 Mb/s	54 Mb/s	

Not BWA; for comparison only

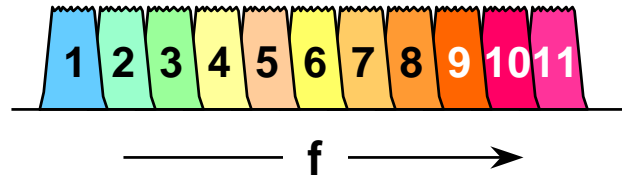


Comparison of Wireless System Capacities

	800 Cellular (A,B)			1900 PCS (A, B, C)			1900 PCS (D, E, F)		
Fwd/Rev Spectrum kHz.	12,500	12,500	12,500	15,000	15,000	15,000	5,000	5,000	5,000
Technology	AMPS	TDMA	CDMA	TDMA	GSM	CDMA	TDMA	GSM	CDMA
Req'd C/I or Eb/No, db	17	17	6	17	12	6	17	12	6
Freq Reuse Factor, N	7	7	1	7	4	1	7	4	1
RF Signal BW, kHz	30	30	1250	30	200	1250	30	200	1250
Total # RF Carriers	416	416	9	500	75	11	166	25	3
RF Sigs. per cell @N	59	59	9	71	18	11	23	6	3
# Sectors per cell	3	3	3	3	3	3	3	3	3
#CCH per sector	1	1	0	1	0	0	1	0	0
RF Signals per sector	18	18	9	22	6	11	6	2	3
Voicepaths/RF signal	1	3	22	3	8	22	3	8	22
SH average links used	1	1	1.66	1	1	1.66	1	1	1.66
Unique Voicepaths/carrier	1	3	13.253	3	8	13.253	3	8	13.253
Voicepaths/Sector	18	54	198	66	48	242	18	16	66
Unique Voicepaths/Sector	18	54	119	66	48	145	18	16	39
P.02 Erlangs per sector	11.5	44	105.5	55.3	38.4	130.9	11.5	9.83	30.1
P.02 Erlangs per site	34.5	132	316.5	165.9	115.2	392.7	34.5	29.49	90.3
Capacity vs. AMPS800	1	3.8	9.2	4.8	3.3	11.4	1.0	0.9	2.6

Capacity of Multicarrier CDMA Systems

CDMA Carrier Frequencies



Fwd/Rev Spectrum kHz.	12,500	1,800	3,050	4,300	5,550	6,800	8,050	9,300	10,550	11,800	13,050	14,300
Technology	AMPS	CDMA	CDMA	CDMA	CDMA	CDMA	CDMA	CDMA	CDMA	CDMA	CDMA	CDMA
Req'd C/I or Eb/No, db	17	6	6	6	6	6	6	6	6	6	6	6
Freq Reuse Factor, N	7	1	1	1	1	1	1	1	1	1	1	1
RF Signal BW, kHz	30	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250
Total # RF Carriers	416	1	2	3	4	5	6	7	8	9	10	11
RF Sigs. per cell @N	59	1	2	3	4	5	6	7	8	9	10	11
# Sectors per cell	3	3	3	3	3	3	3	3	3	3	3	3
#CCH per sector	1	0	0	0	0	0	0	0	0	0	0	0
RF Signals per sector	18	1	2	3	4	5	6	7	8	9	10	11
Voicepaths/RF signal	1	22	22	22	22	22	22	22	22	22	22	22
SH average links used	1	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66
Unique Voicepaths/carrier	1	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3
Voicepaths/Sector	18	22	44	66	88	110	132	154	176	198	220	242
Unique Voicepaths/Sector	18	13	26	39	53	66	79	92	106	119	132	145
P.02 Erlangs per sector	11.5	7.4	18.4	30.1	43.1	55.3	67.7	80.2	93.8	105.5	119.1	130.9
P.02 Erlangs per site	34.5	22.2	55.2	90.3	129.3	165.9	203.1	240.6	281.4	316.5	357.3	392.7
Capacity vs. AMPS800	1	0.64	1.60	2.6	3.7	4.8	5.9	7.0	8.2	9.2	10.4	11.4