

Wireless LANs

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Introduction to Wireless Communications

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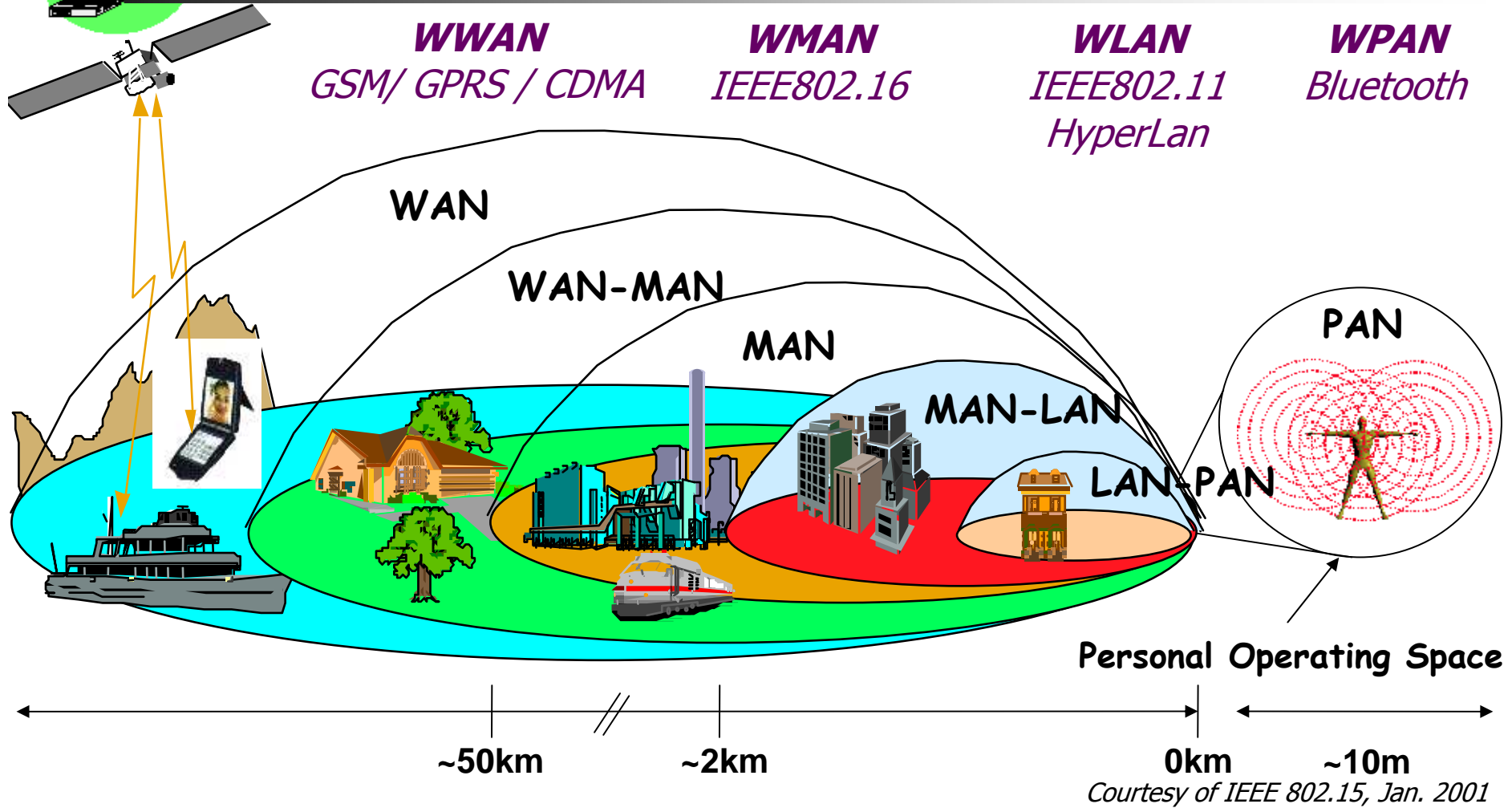


Outline

- **Wireless Classifications**
- Wireless World (2G, 3G, ...)
- Basic Wireless Knowledge
 - Principles
 - Wireless Voice Communications
- Wireless Data Communications



Wireless Classifications





Outline

- Wireless Classifications
- **Wireless World (2G, 3G, ...)**
- Basic Wireless Knowledge
 - Principles
 - Wireless Voice Communications
- Wireless Data Communications



Wireless World

- Mobile (telephony)
 - On the move
 - GSM
 - 9.6 kbps – 40 kbps
- Nomadic
 - Within a building (low mobility)
 - Wireless LAN
 - 2 Mbps – 25 Mbps and more
- Satellite



1G (First Generation)

- Analog
- Circuit-switched Network
- Low voice quality
- No security
- Low capacity
- AMPS

(Advanced Mobile Phone System 800-900MHz)



2G (Second Generation)

- Digital encoding
- High bit rate voice
- Limited data communications (tens Kbps)
- GSM, D-AMPS (TDMA) and CDMA
- Auxiliary services (data, fax and SMS)
- Some levels of encryption



2.5G

- Extend 2G systems (GSM)
- Packet-switched connection (GPRS)
- Higher data rate (up to hundred Kbps)



“Calypso Wireless”
with the WiFi
networks as well as
the GSM/GPRS
(May 2005)



“Vodafone 802SE”
Dual Mode W-CDMA and GSM
900/1800/1900 MHz, Digital Cam
1.3M, Bluetooth, Memory Stick



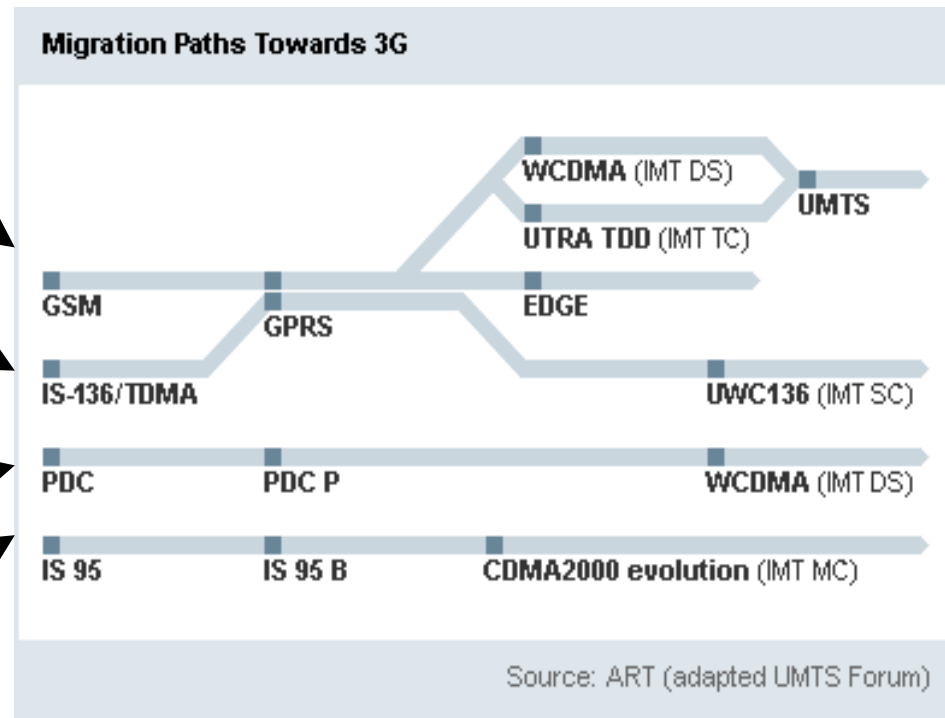
Migration Paths → 3G

GSM: Europe & Worldwide

IS-136: (US-TDMA and Digital AMPS) in the U.S.

PDC: (Personal Digital Communications) in Japan

IS-95: (cdmaOne) in the U.S.





3G (Third Generation)

- Higher data rates (Mbps)
- More than voice...
 - Support bandwidth-hungry applications
 - Full-motion video
 - Video-conferencing
 - Full Internet access (IP)
- 3G & WLAN: complementary relationship

3G Phone



Android



- by Google
- based on Linux Kernel
- OS for mobile phone
- API / middleware
- Application Software (e.g. Calendar)
- Support 3G/BT



HTC Dream

Intelligent Wireless Network Group (IWING)

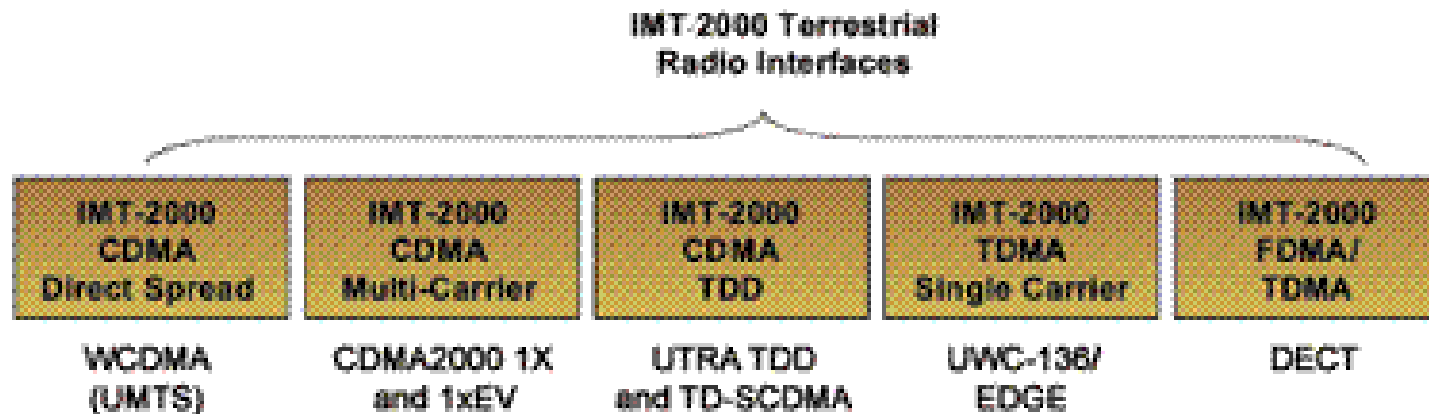
CPE Department, Kasetsart University



IMT 2000



- Support data services at min. TX rates of
 - 144 kbps in mobile (outdoor)
 - 2 Mbps in fixed (indoor)
- W-CDMA, CDMA2000





IMT 2000 Implementation

- Radio Technology: **WCDMA**
Spectrum: **2 GHz Bands**
 - Japan, Norway, Finland, Sweden, Austria, France, UK
- Radio Technology: **cdma2000**
Spectrum: **800/900/1800/1900 MHz Bands**
 - Korea, USA, Canada, Brazil, Japan, Australia, Indonesia

<http://www.itu.int/ITU-D/imt-2000/implementation.html>



CDMA2000



cdmaOne (IS-95A)	<ul style="list-style-type: none">•Voice•Data up to 14.4 Kbps
cdmaOne (IS-95B)	<ul style="list-style-type: none">•Voice•Data up to 115 Kbps
CDMA2000 1x	<ul style="list-style-type: none">•2x increases in voice capacity•Up to 307 kbps*packet data on a single (1.25 MHz) carrier•First 3G system for any technology worldwide
CDMA2000 1xEV	<ul style="list-style-type: none">•Optimized, very high-speed data (Phase 1)•Up to 2.4Mbps*packet data on a single (1.25 MHz) carrier.•Integrated voice and data (Phase 2); up to 3.09 Mbps

<http://www.cdg.org/technology/3g/evolution.asp>



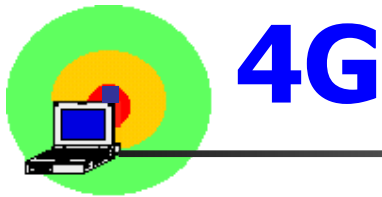
3.5 G

- NTT DoCoMo (i-mode service)
- HSDPA High-Speed Downlink Packet Access (3.5G) Tx speed up to 14Mbps
- Same 5MHz frequency BW as W-CDMA (3G)
- Expected launch: ending March 2006

HSPA (High-Speed Packet Access)



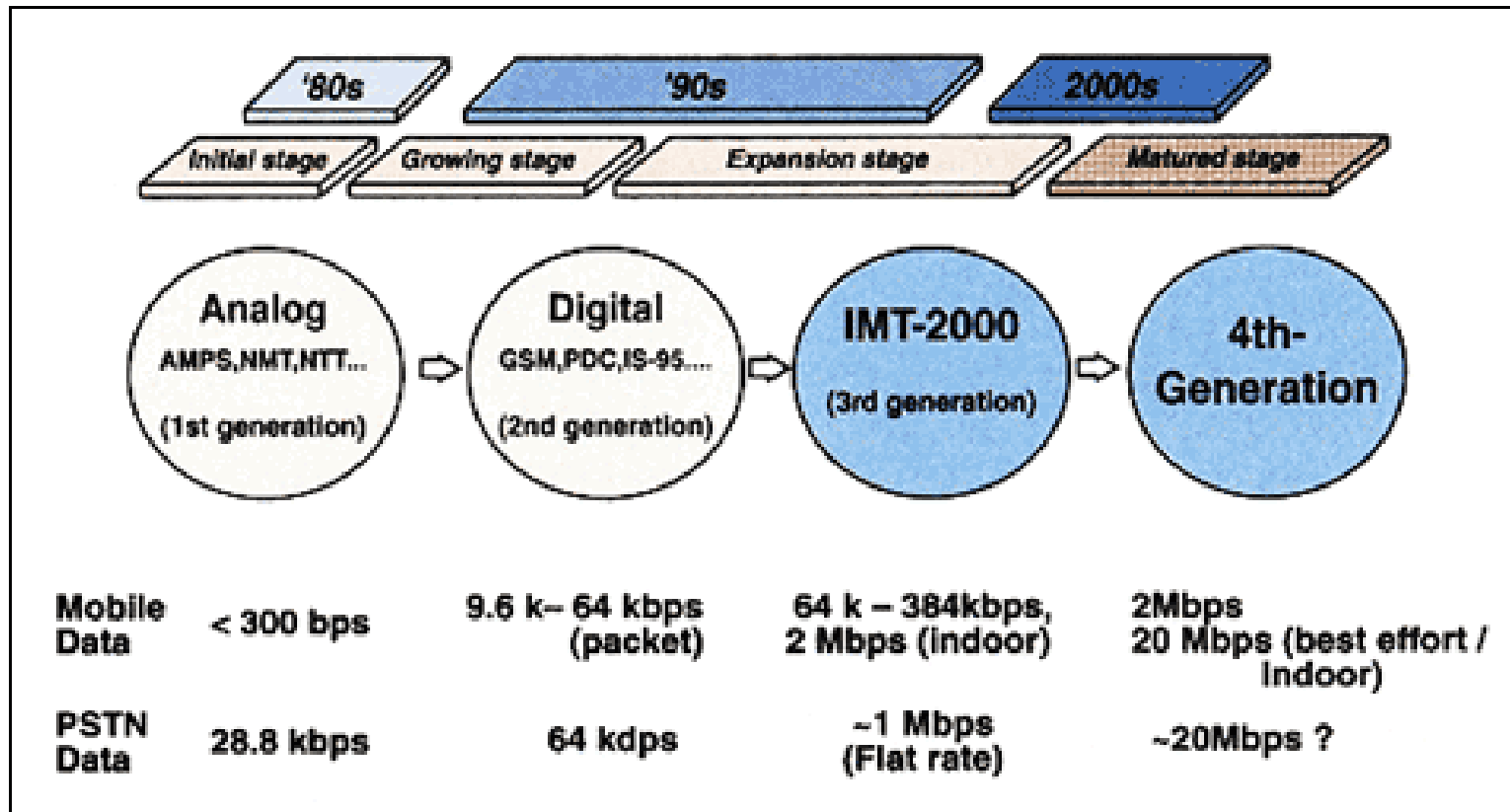
- Mobile Telephone protocol
- Extension of WCDMA
- HSDPA (High-Speed Downlink Packet Access)
 - UMTS
 - 1.8, 3.6, 7.2, 14.4 Mbps
 - Faster than EDGE = 36 times
 - Faster than GPRS = 100 times
- HSUPA (High-Speed Uplink Packet Access)
 - By Nokia
 - Up to 5.76, 11.5 Mbps (3GPP: 3G Partnership Project)



- Beyond IMT-2000
- High BW (~100 Mbps)
- Support QoS, HDTV, mobile TV, Digital Video Broadcasting (DVB)
- NTT DoCoMo of Japan
 - VSF-OFCDM (4G) achieves packet transmission with a maximum downlink of 100Mbps and maintains high-quality reception

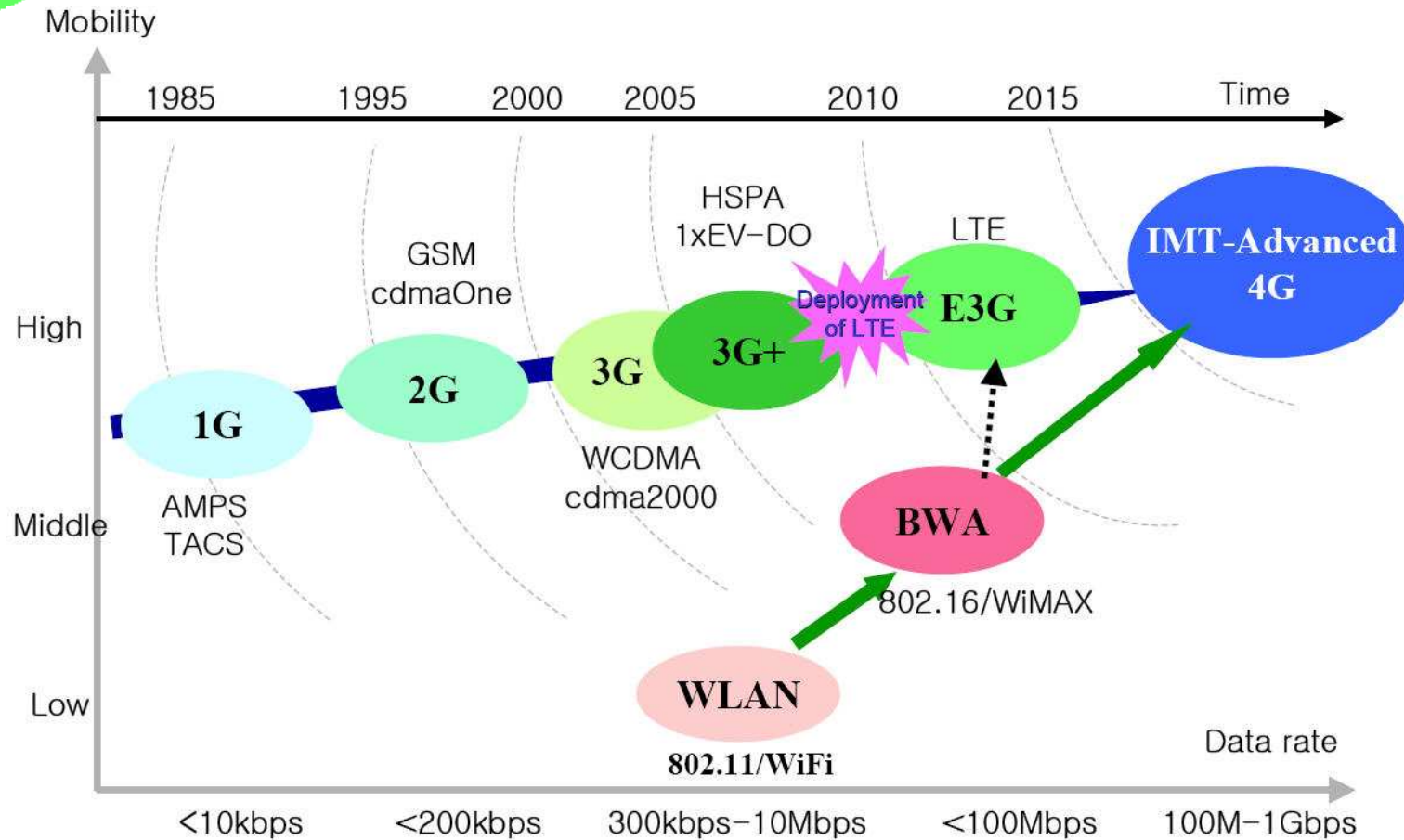


Evolution of the system



Source: Mobile Communications International

Wireless System Roadmap



<http://www.dolcera.com/wiki/index.php?title=Image:Roadmap.jpg>

Cellular Mobile Tel. Subscribers (2003)



<http://www.itu.int/ITU-D/ict/statistics>

Cellular subscribers

World

	Cellular mobile subscribers					As % of total telephone subscribers 2003
	(k)		CAGR (%) 1998-03	Per 100 inhabitants 2003	% Digital 2003	
	1998	2003				
84 United States	69'209.3	158'722.0	18.1	54.58	93.4	46.7
85 Uruguay	151.3	652.0	[02] 44.1	19.26	...	[02] 40.8
86 Venezuela	2'009.8	7'015.7	28.4	27.30	...	71.2
Americas	95'066.8	295'416.2	25.5	34.68	67.6	50.3
93 Cambodia	61.3	498.4	52.0	3.52	77.3	93.2
94 China	23'863.0	269'953.0	62.4	21.48	100.0	50.7
95 Georgia	60.0	711.2	64.0	14.54	100.0	52.0
96 Hong Kong, China	3'174.4	7'349.2	18.3	107.92	100.0	65.9
97 India	1'195.4	26'154.4	85.4	2.47	100.0	34.8
98 Indonesia	1'065.8	18'800.0	77.5	8.74	...	68.9
99 Iran (I.R.)	390.0	3'376.5	54.0	5.09	100.0	18.8
100 Israel	2'147.0	6'500.0	24.8	96.07	100.0	67.7
101 Japan	47'307.6	86'655.0	12.9	67.90	100.0	59.0
121 Singapore	1'094.7	3'577.5	26.7	85.25	100.0	65.4
122 Sri Lanka	174.2	1'393.4	51.6	7.27	77.4	59.7
123 Syria	-	1'185.0	-	6.75	100.0	36.1
124 Taiwan, China	4'727.0	25'799.8	40.4	114.14	100.0	65.9
125 Tajikistan	0.4	47.6	157.6	0.73	...	16.3
126 Thailand	1'977.0	24'864.0	65.9	39.42	85.7	79.0

Cellular Mobile Tel. Subscribers (2007): Americas

<http://www.itu.int/ITU-D/ict/statistics>



	<i>Mobile cellular subscribers</i>					<i>As % of total</i>
	<i>(000s)</i>		<i>CAGR</i>	<i>per 100</i>	<i>%</i>	<i>telephone subscribers</i>
	<i>2002</i>	<i>2007</i>	<i>(%)</i>	<i>inhabitants</i>	<i>Digital</i>	
			<i>2002 - 07</i>	<i>2007</i>	<i>2007</i>	<i>2007</i>
64 Canada	11'872.0	20'277.4	11.3	61.68	...	52.6
80 Mexico	25'928.3	66'559.5	20.8	62.48	...	77.1
Americas	255'451.3	666'133.3	21.1	73.22	30.5	70.5

Cellular Mobile Tel. Subscribers (2007): Asia

<http://www.itu.int/ITU-D/ict/statistics>



	<i>Mobile cellular subscribers</i>					<i>As % of total telephone subscribers</i>
	<i>(000s)</i>		<i>CAGR</i>	<i>per 100</i>	<i>%</i>	
	<i>2002</i>	<i>2007</i>	<i>(%)</i>	<i>inhabitants</i>	<i>Digital</i>	
		<i>2002 - 07</i>	<i>2007</i>	<i>2007</i>	<i>2007</i>	
100 Bhutan	-	149.4	-	...	100.0	83.3
102 Cambodia	380.0	2'583.3	46.7	17.89	...	98.6
103 China	206'005.0	547'306.0	21.6	41.19	100.0	59.9
107 India	13'000.0	233'620.0	78.2	19.98	...	85.6
108 Indonesia	11'700.0	93'386.9	51.5	40.32	...	82.7
115 Korea (Rep.)	32'342.5	43'497.5	6.1	90.20	100.0	66.0
118 Lao P.D.R.	55.2	1'478.4	93.0	25.23	100.0	94.0
120 Macao, China	276.1	794.3	23.5	165.10	100.0	81.7
121 Malaysia	9'053.0	23'347.0	20.9	87.86	100.0	84.3
124 Myanmar	48.0	271.4	41.4	0.56	...	27.7
129 Philippines	15'383.0	57'344.8	30.1	65.19	100.0	93.6
132 Singapore	3'313.0	5'924.1	12.3	133.54	100.0	76.1
135 Taiwan, China	24'390.5	24'287.0	-0.1	106.05	100.0	63.0
142 Viet Nam	1'902.4	23'730.2	65.7	27.16	100.0	45.4
Asia	443'937.4	1'514'586.4	27.8	38.10	69.4	70.8



Internet Hosts (2003)

<http://www.itu.int/ITU-D/ict/statistics>

	<i>Internet</i>				<i>PCs</i>	
	<i>Hosts Total 2003</i>	<i>Hosts per 10'000 inhab. 2003</i>	<i>Users (k) 2003</i>	<i>Users per 10'000 inhab. 2003</i>	<i>Total (k) 2003</i>	<i>Per 100 inhab. 2003</i>
84 United States	162'208'993	5'577.84	161'632.4	5'558.01	190'000 [02]	65.98
85 Uruguay	87'630	257.04	400.0 [01]	1'190.12	370 [01]	11.01
86 Venezuela	35'301	13.74	1'549.5	602.98	1'536 [02]	6.09
Americas	171'316'940	2'009.62	224'477.8	2'644.17	239'787	29.02
93 Cambodia	818	0.58	35.0	24.75	32	0.23
94 China	160'421	1.28	79'500.0	632.48	35'500 [02]	2.76
95 Georgia	4'927	10.07	117.0	239.17	172	3.52
96 Hong Kong, China	591'993	869.29	3'212.8	4'717.70	2'864 [02]	42.20
97 India	86'871	0.82	18'481.0	174.86	7'500 [02]	0.72
98 Indonesia	62'036	2.88	8'080.0	375.65	2'519 [02]	1.19
99 Iran (I.R.)	5'052	0.76	4'800.0	723.66	6'000	9.05
100 Israel	435'625	643.87	2'000.0 [02]	3'014.05	1'610 [02]	24.26
101 Japan	12'962'065	1'015.68	61'600.0	4'826.87	48'700 [02]	38.22
121 Singapore	484'825	1'155.31	2'135.0	5'087.65	2'590 [02]	62.20
122 Sri Lanka	1'882	0.98	250.0	130.45	325	1.70
123 Syria	11	0.01	610.0	347.58	500	2.85
124 Taiwan, China	2'777'085	1'228.55	8'830.0	3'906.29	10'655	47.14
125 Tajikistan	75	0.11	4.1	6.30
126 Thailand	103'700	16.44	6'971.5	1'105.19	2'461 [02]	3.98

Internet Host (2007)



<http://www.itu.int/ITU-D/ict/statistics>

	<i>Internet</i>				<i>Broadband Subscribers</i>	
	<i>Subscribers</i>	<i>Subscribers per</i>	<i>Users</i>	<i>Users per</i>	<i>Total</i>	<i>Per 100</i>
	<i>(000s)</i>	<i>100 inhab.</i>	<i>(000s)</i>	<i>100 inhab.</i>	<i>(000s)</i>	<i>inhab.</i>
	<i>2007</i>	<i>2007</i>	<i>2007</i>	<i>2007</i>	<i>2007</i>	<i>2007</i>
64 Canada	10'163.0	30.91	23'999.5	73.00	9'075.0	27.60
80 Mexico	5'836.6	5.48	22'104.1	20.75	4'548.8	4.27
Americas	107'565	12.06	392'407.1	43.16	99'281	10.94



Internet Hosts (2007)

<http://www.itu.int/ITU-D/ict/statistics>

	<i>Internet</i>				<i>Broadband Subscribers</i>	
	<i>Subscribers</i>	<i>Subscribers per</i>	<i>Users</i>	<i>Users per</i>	<i>Total</i>	<i>Per 100</i>
	<i>(000s)</i> <i>2007</i>	<i>100 inhab.</i> <i>2007</i>	<i>(000s)</i> <i>2007</i>	<i>100 inhab.</i> <i>2007</i>	<i>(000s)</i> <i>2007</i>	<i>inhab.</i> <i>2007</i>
100 Bhutan	6.1	...	40.0	...	-	...
102 Cambodia	14.7	0.10	70.0	0.48	8.4	0.06
103 China	150'264.0	11.31	212'580.8	16.00	66'414.0	5.00
104 D.P.R. Korea	-	-	-	-	-	-
107 India	13'490.0	1.15	81'000.0	6.93	3'130.0	0.27
108 Indonesia	3'126.0	1.35	25'000.0	10.79	294.5	0.13
115 Korea (Rep.)	14'710.0	30.50	36'794.8	76.30	14'710.0	30.50
118 Lao P.D.R.	5.5	0.09	100.0	1.71	3.6	0.06
121 Malaysia	4'930.9	18.56	14'792.7	55.67	1'010.9	3.80
124 Myanmar	7.1	0.01	40.0	0.08	1.5	-
129 Philippines	2'500.0	2.84	5'300.0	6.03	496.2	0.56
132 Singapore	1'927.6	43.45	3'104.9	69.99	896.2	20.20
135 Taiwan, China	5'968.4	26.06	14'760.0	64.45	4'790.2	20.92
142 Viet Nam	5'240.6	6.00	17'872.0	20.45	1'294.1	1.48
Asia	251'804	6.59	576'544.5	14.50	128'071	3.27



Outline

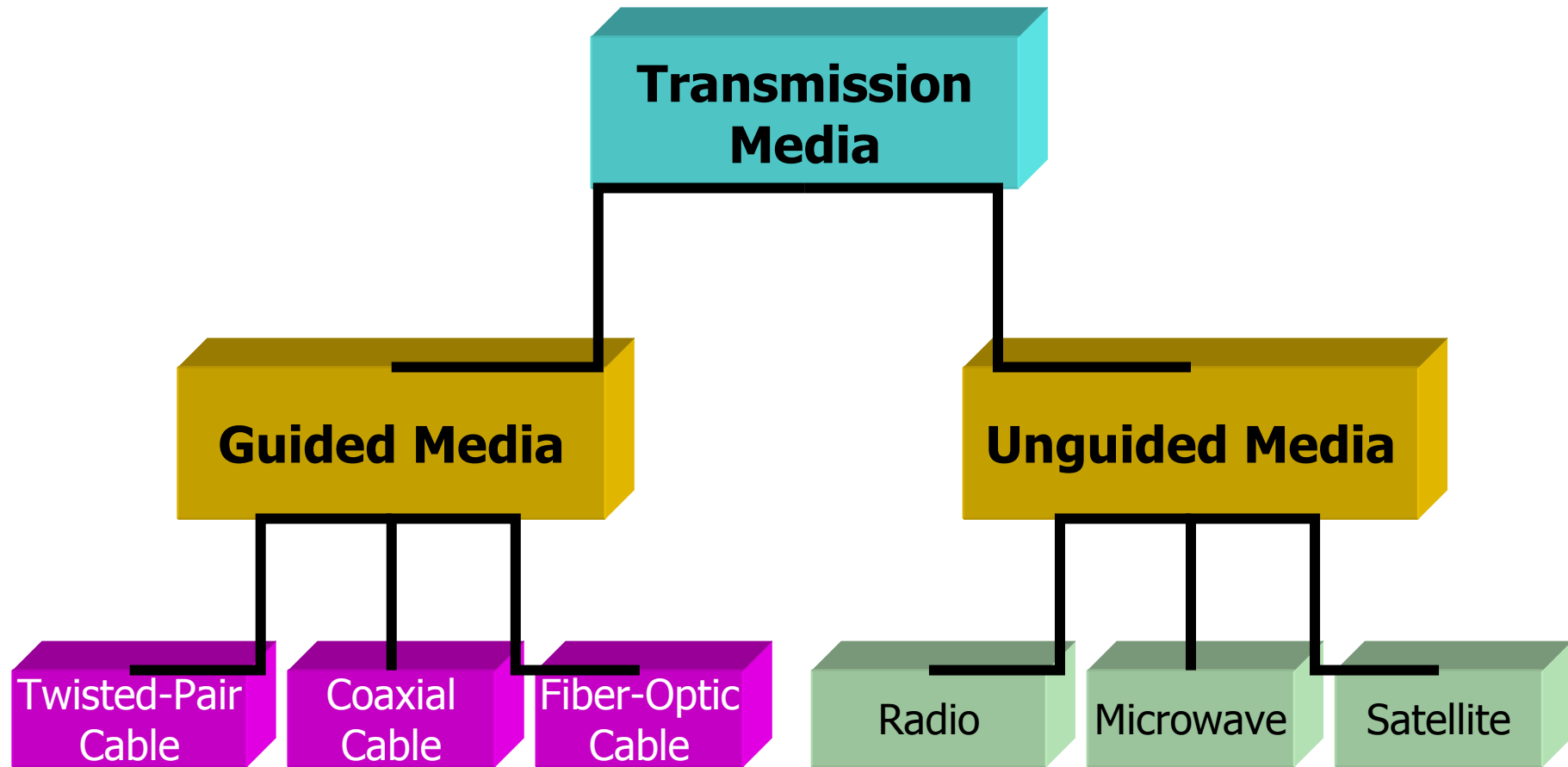
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- **Basic Wireless Knowledge**
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- Wireless Data Communications

Wireless Communication Principle





Communication Media



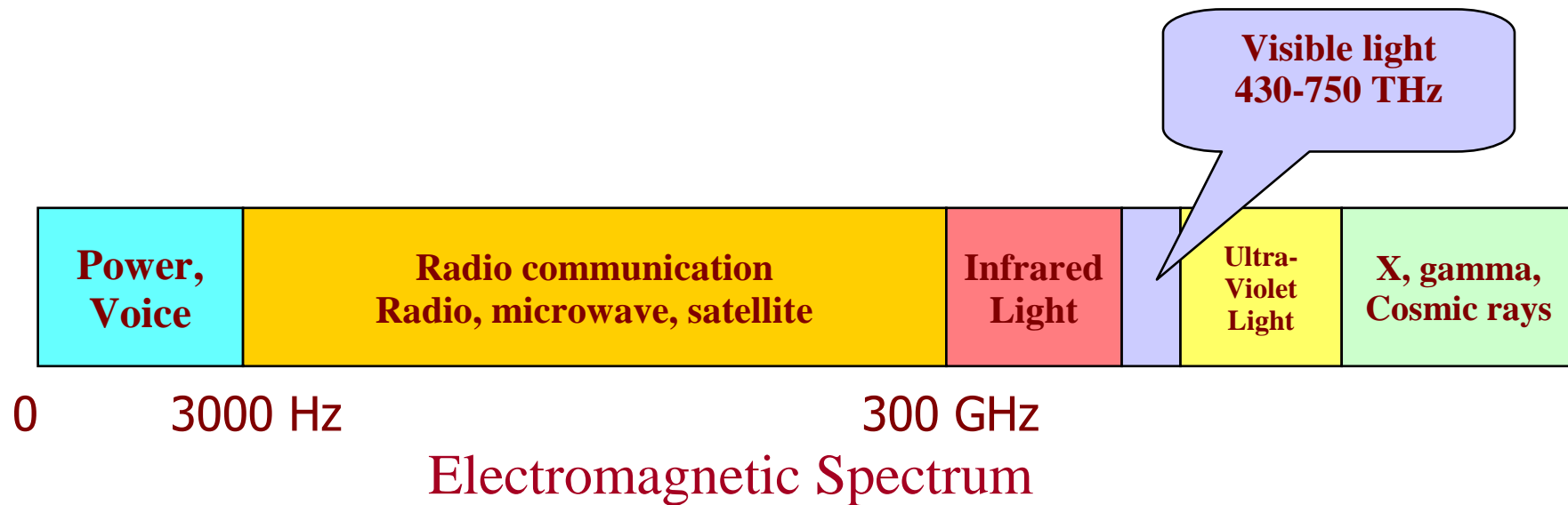


Communication Principle

- How can the information be transmitted?

Information

→ Signals (Electromagnetic Energy)

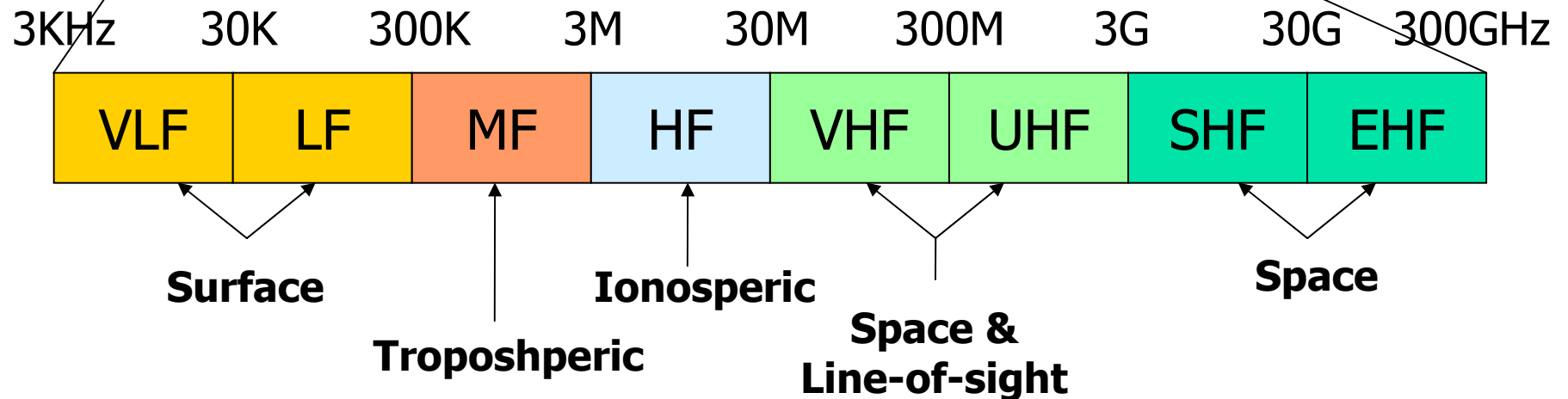




Electromagnetic Spectrum



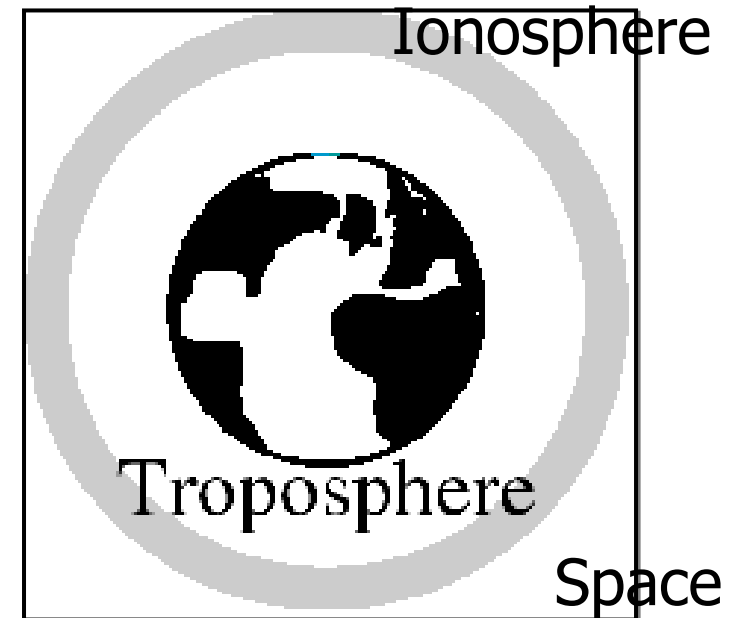
Radio Frequency Allocation: 8 bands





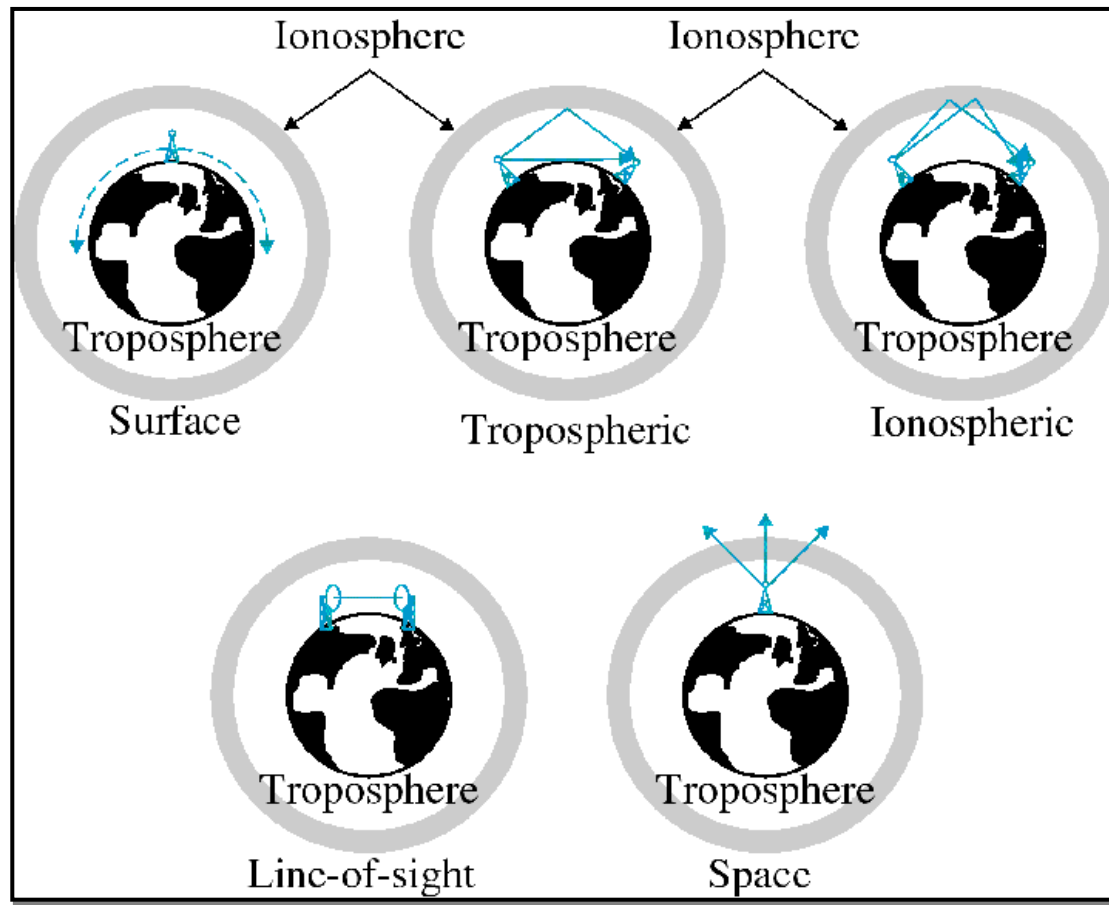
Earth atmosphere

- Troposphere
 - 30 miles from earth
 - Air
 - Clouds, wind, weather
 - Jet plane travel
- Ionosphere
 - Between Troposphere and space
 - Free electrically charged particles





Types of propagation





Surface Propagation: VLF & LF

VLF (in range of 3KHz – 10KHz)

- Low attenuation
- Atmosphere noise (heat & electricity)
- For long-range radio navigation

LF (in range of 30KHz – 300 KHz)

- For long-range radio navigation
- Greater attenuation



Troposphere Propagation: MF

MF (300KHz – 3MHz)

- Distance is limited by reflected angle
- Rely on line-of-sight antennas
- AM radio (535 KHz – 1605 MHz)



Ionosphere Propagation: HF

HF (3 MHz – 30 MHz)

- Amateur radio (Ham radio)
- Citizen's band (CB)
- International Broadcasting



Light-of-sight Propagation: VHF & UHF

VHF (30 MHz – 300 MHz)

- VHF television
- FM radio

UHF (300 MHz – 3 GHz)

- UHF television
- Mobile telephone
- Cellular
- Microwave communication



Space Propagation: SHF & EHF

SHF (3 GHz – 30 GHz)

- Mostly light-of-sight & space
- Terrestrial & satellite microwave
- Radar communication

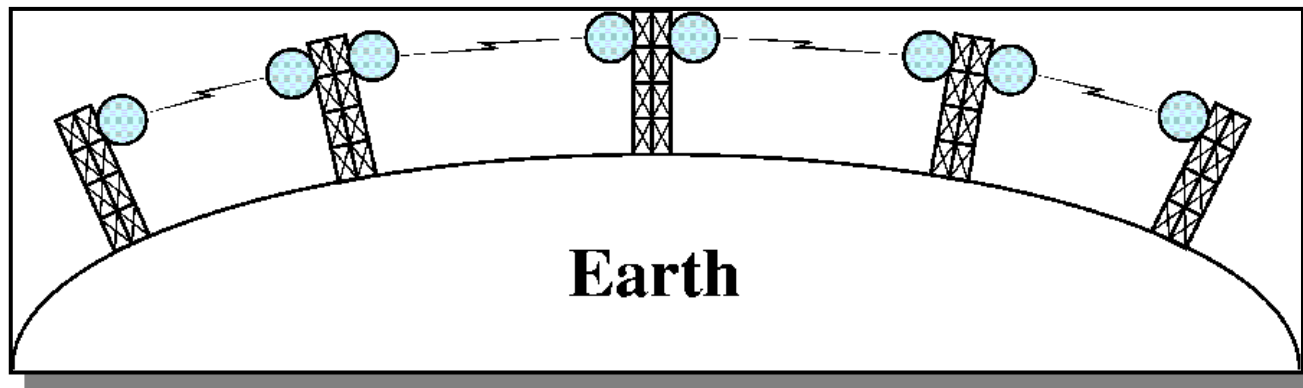
EHF (30 GHz – 300 GHz)

- Radar
- Satellite



Terrestrial Microwave

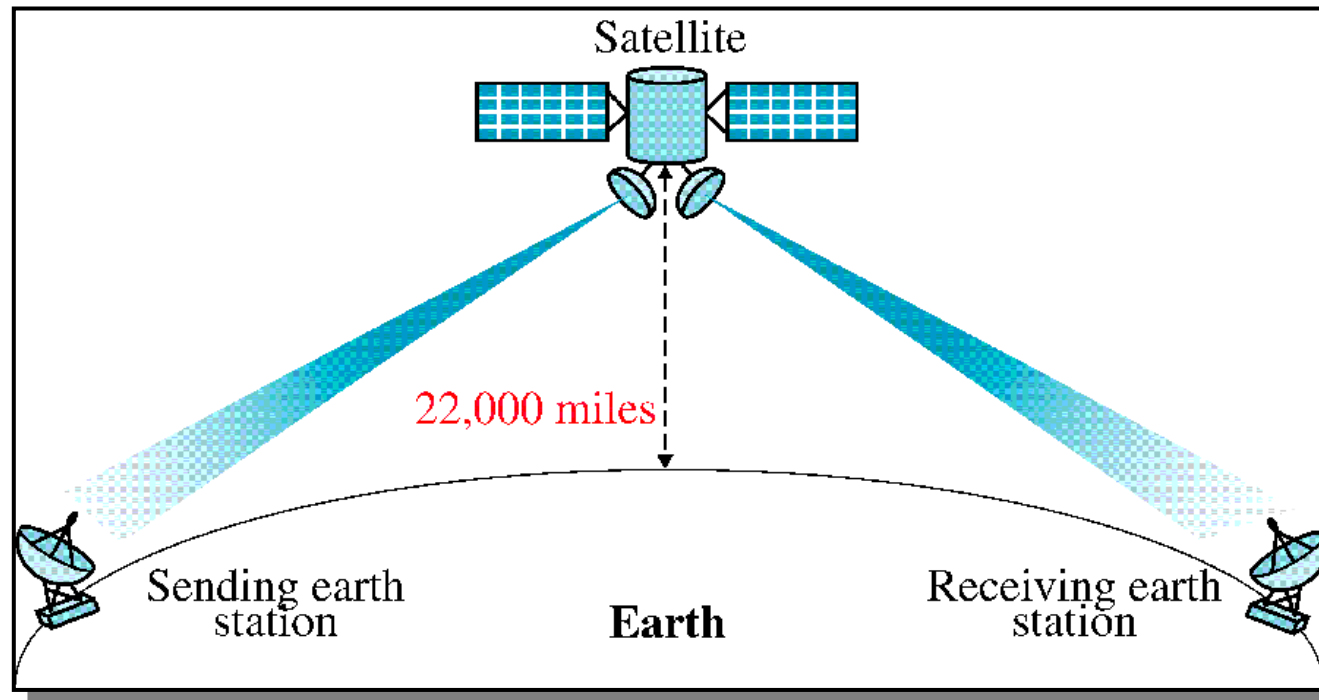
- Need light-of-sight (Do not follow the earth)
- The Taller the antennas, the longer the distance
- Propagate in one direction at a time (2 frequencies for 2-way communication)





Satellite Communication

- Like microwave
- Supertall antenna & repeater





Assignment #1

(แต่ละข้อเลือกทำ 1 ข้อย่อย, ข้อละไม่เกิน 2 หน้า A4)

- 1a. การจัดสรรคลื่นความถี่ทั่วไปในเมืองไทย
(หน่วยงานที่เกี่ยวข้อง/ความถี่ที่ใช้/ข้อกำหนด)
- 1b. แนวโน้ม ระบบโทรศัพท์มือถือในประเทศไทย
(ปัจจุบัน/3G/Services/Applications)

- 2a. ความคืบหน้าเทคโนโลยี WiFi
- 2b. ความคืบหน้าเทคโนโลยี WiMAX

Due Date: Tue June 18, 2009 (before class start)

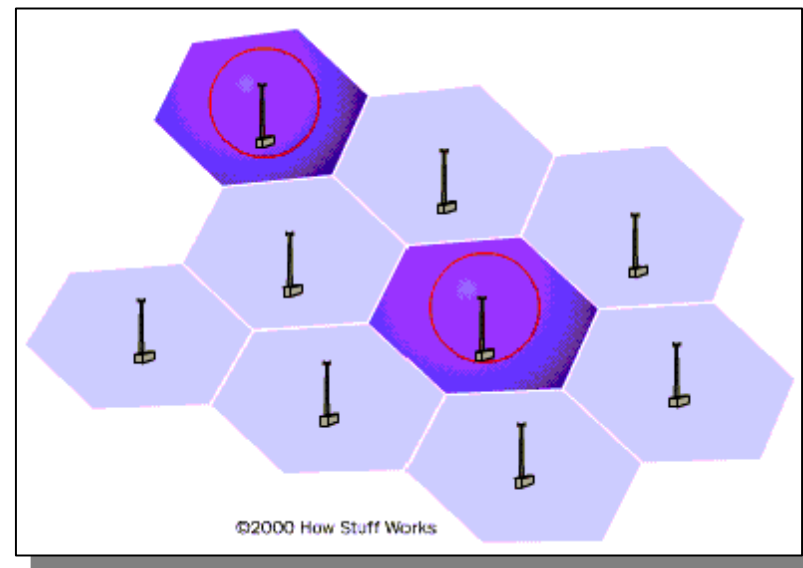
Wireless Voice Communication





Cellular System

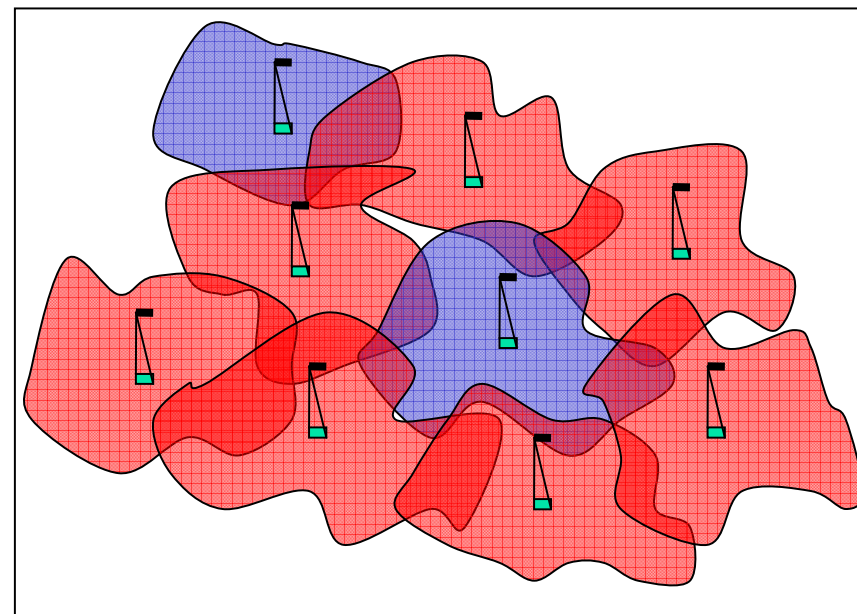
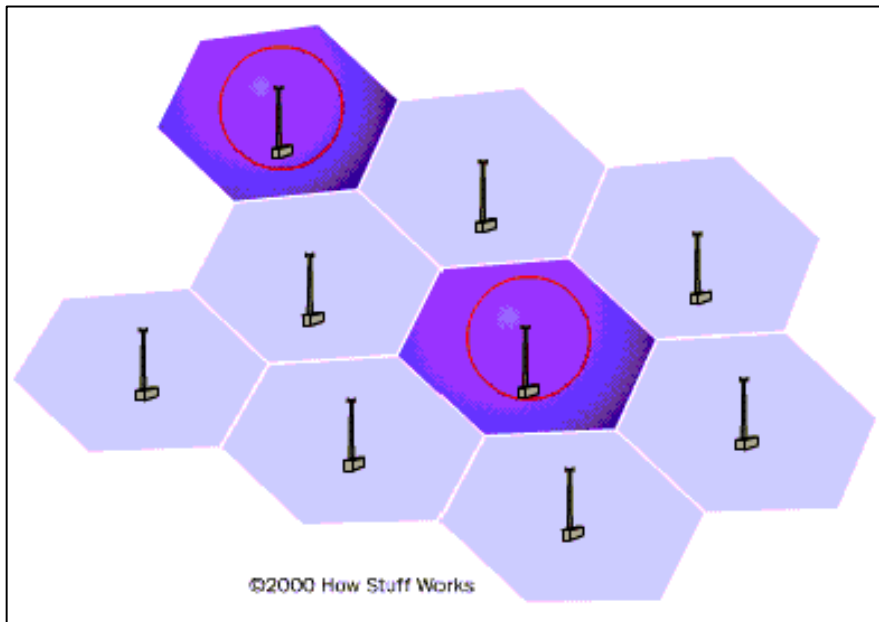
- Geographical Region has been divided into circular areas called "**Cells**"
- Transmission Power \rightarrow Cell size
- Frequency reuse





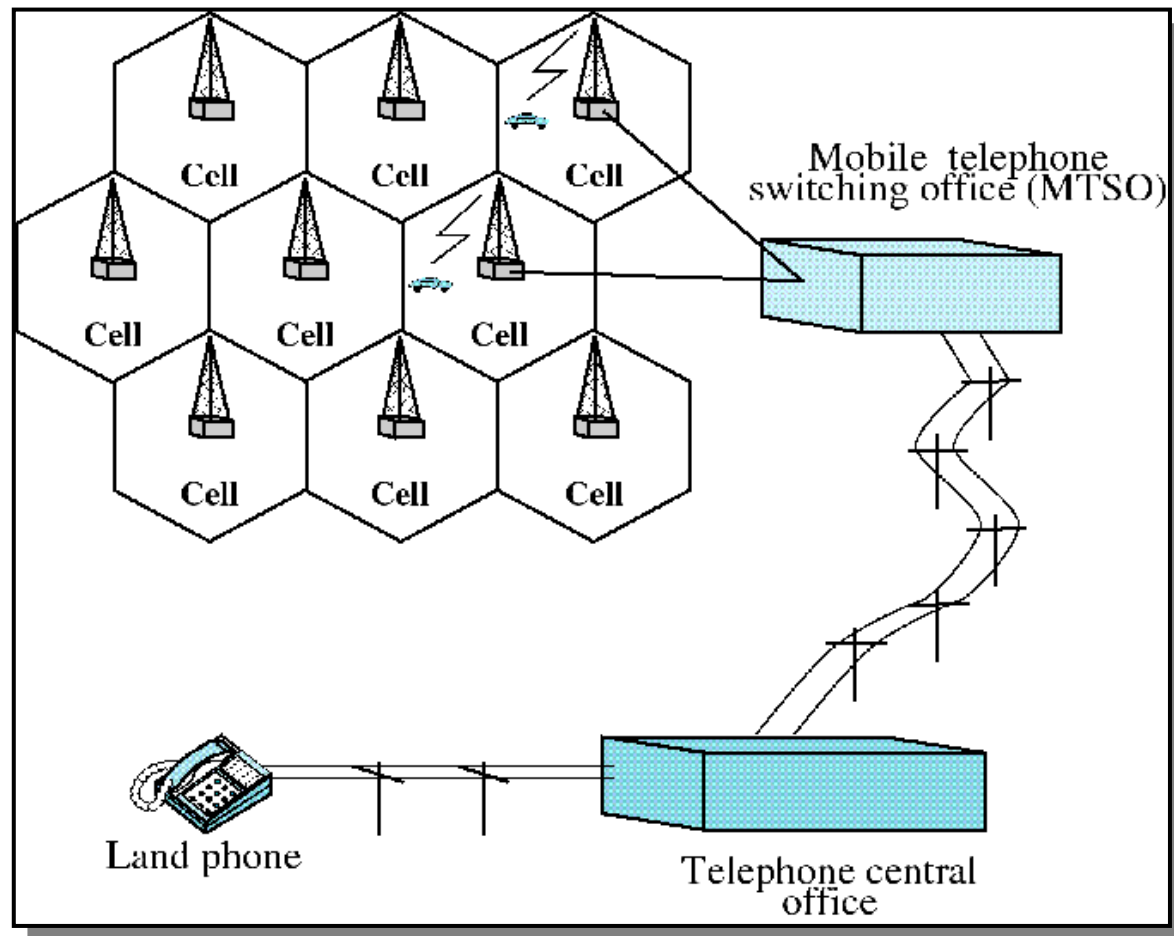
Actual Cell Layout

- Hexagonal shape → used in designing
- Irregular shape → actual cell layout





Cellular Telephone System





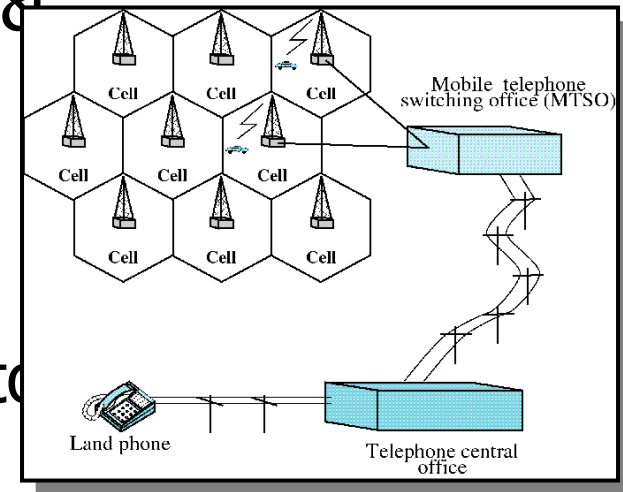
Mobile phone power up

- Listen for System Identification Code (**SID**) on **control channel** (special freq)
- Compare received SID with its own preprogrammed SID in the phone
 - If SID match → in Home System
 - Nothing on control channel → out of range
- Mobile phone sends registration request & SID to MTSO for location tracking database



Mobile phone places a call (1)

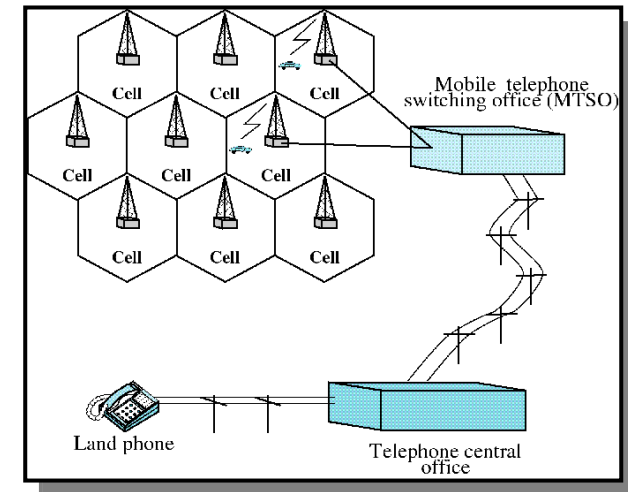
- Key the number and send
- **Mobile phone** scans the bands & selects strong signal channel
- Send phone number to **Cell Office**
- Cell office relays phone number to **MTSO**





Mobile phone places a call (2)

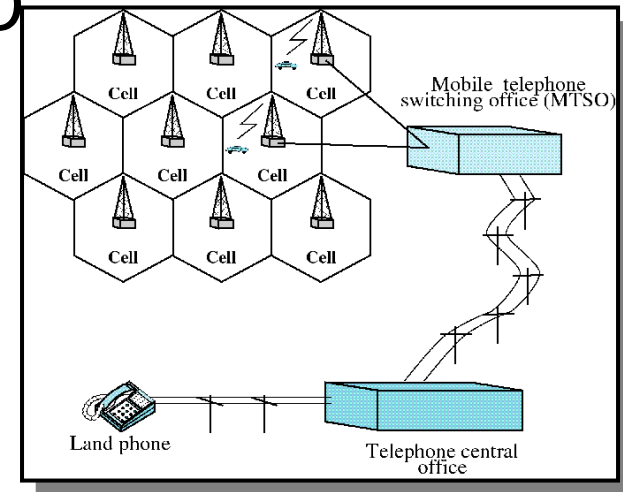
- MTSO → **Telephone Central Office**
- If **called party** available, make connection → MTSO
- MTSO assigns unused channel
- Mobile tuning to the assigned channel





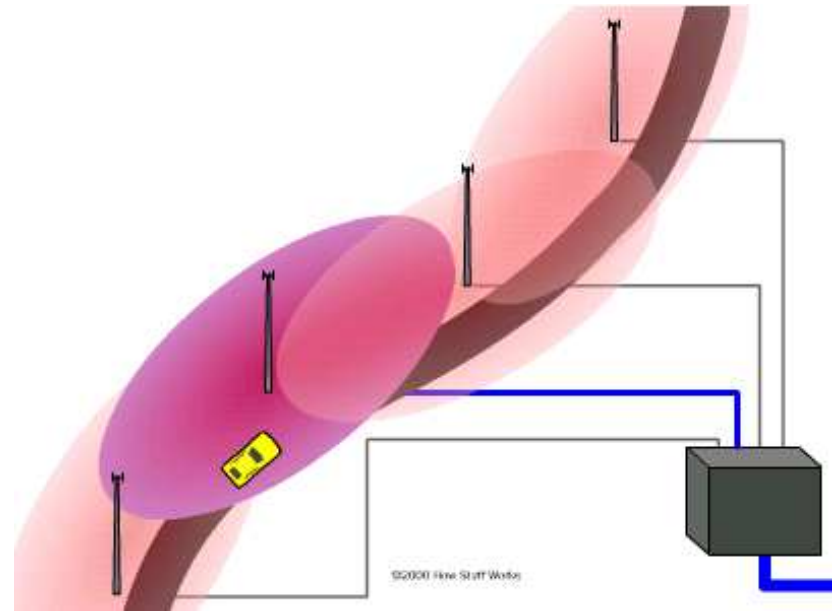
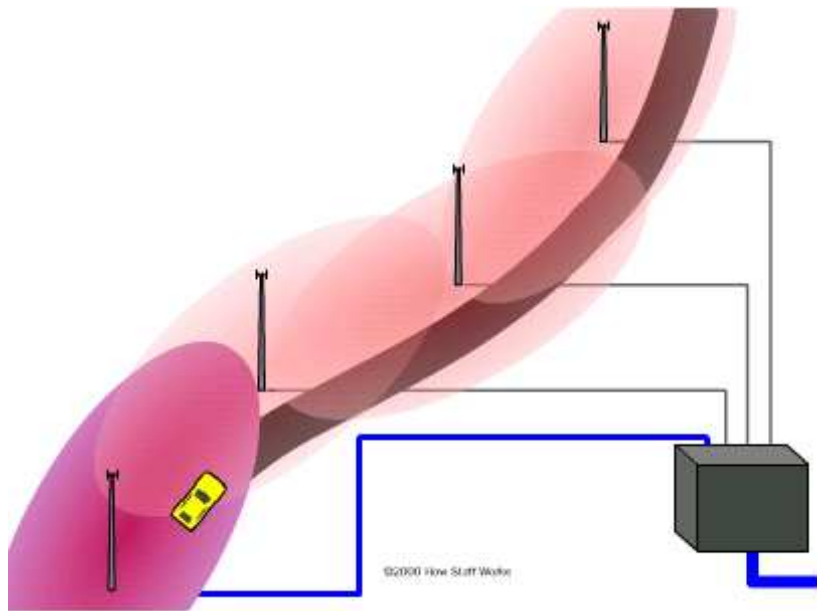
Land phone places a call

- Key the number
- Telephone central office → MTSO
- MTSO searches for mobile location (call paging)
- If found, MTSO → send ringing
- Assign a voice channel





Mobility





Hand off

- As mobile moves to the cell edge
- Current base station → get weaker signal
- New base station → get stronger signal
- Signal strength measuring → all frequencies
- Two base stations communicate through MTSO
- Mobile phone gets the new assign frequency on the control channel



Roaming

- Mobile phone receives SID that does not match with its own SID → Roaming
- Current MTSO → Home MTSO to verify



Analog System

- Advanced Mobile Phone System (AMPS)
- 824 MHz – 894 MHz
- 832 frequencies
 - 790 Voice freq & 42 Data freq (reg. , paging)
- One channel (2 freq for Tx and Rx)
 - 395 voice channels & 21 data channels
- Voice (30 KHz)
- 45MHz Tx/Rx seperation → interference



Digital System

- Same radio technology as Analog
- Analog cannot be compressed
- Digital system converts voice → binary info
- Then compress the data info (3-10 times)
- Need more processing power



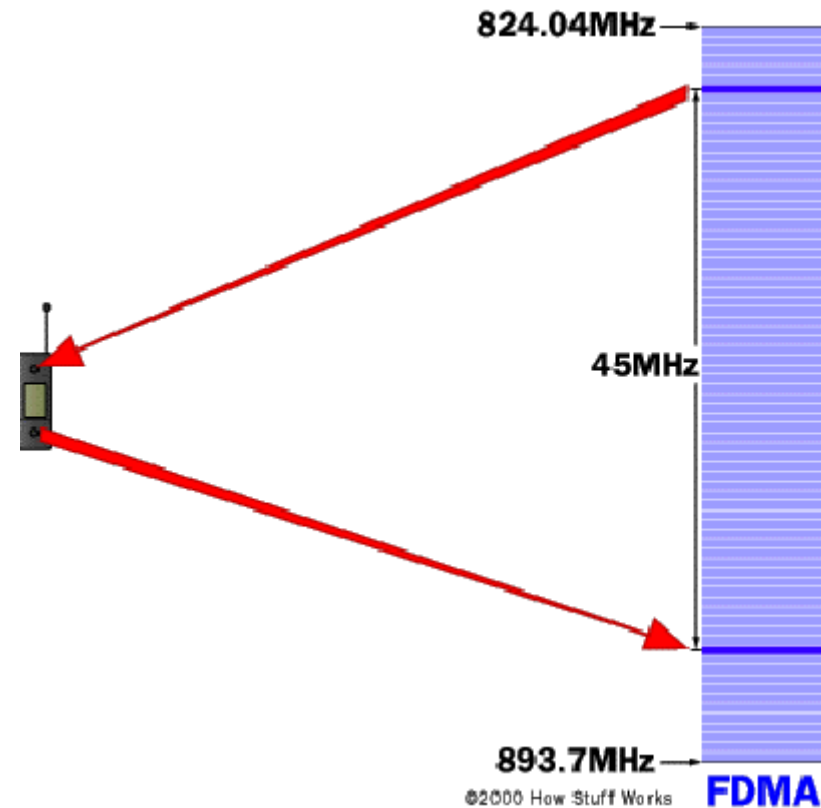
Cellular Access Technologies

- Frequency Division Multiple Access (FDMA)
- Time Division Multiple Access (TDMA)
- Code Division Multiple Access (CDMA)



FDMA

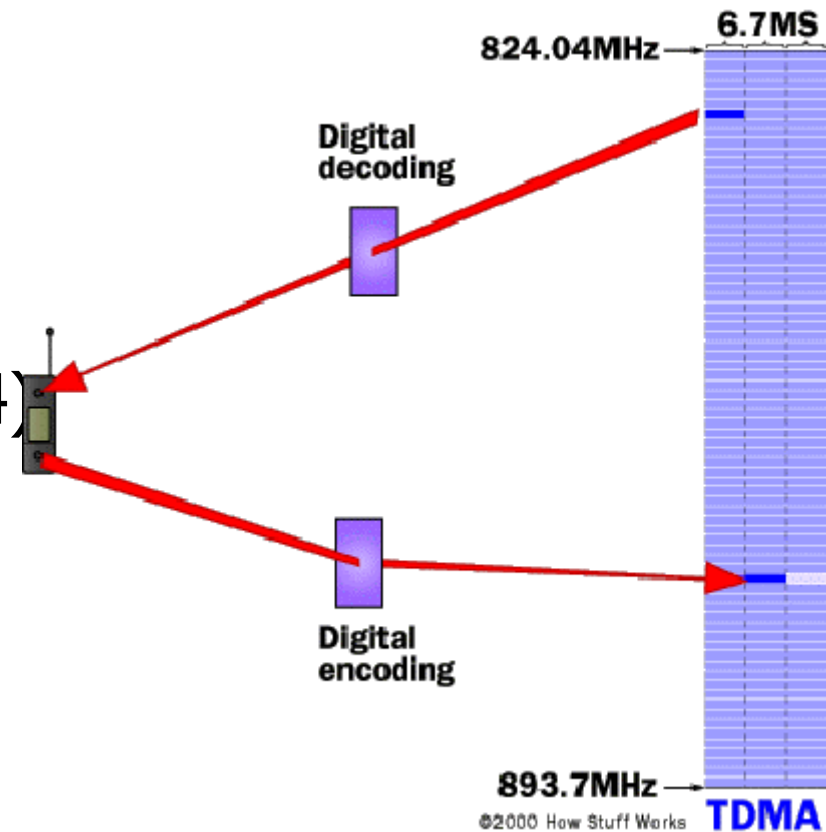
- Mainly used in Analog System
- Voice channel \rightarrow uniform BW range
- Not efficiency





TDMA

- 30 KHz wide, 6.7 ms long (3 time slots)
- 3 times capacity over Analog
- Operate in 800 MHz (IS-54) & 1900 MHz (IS-136)





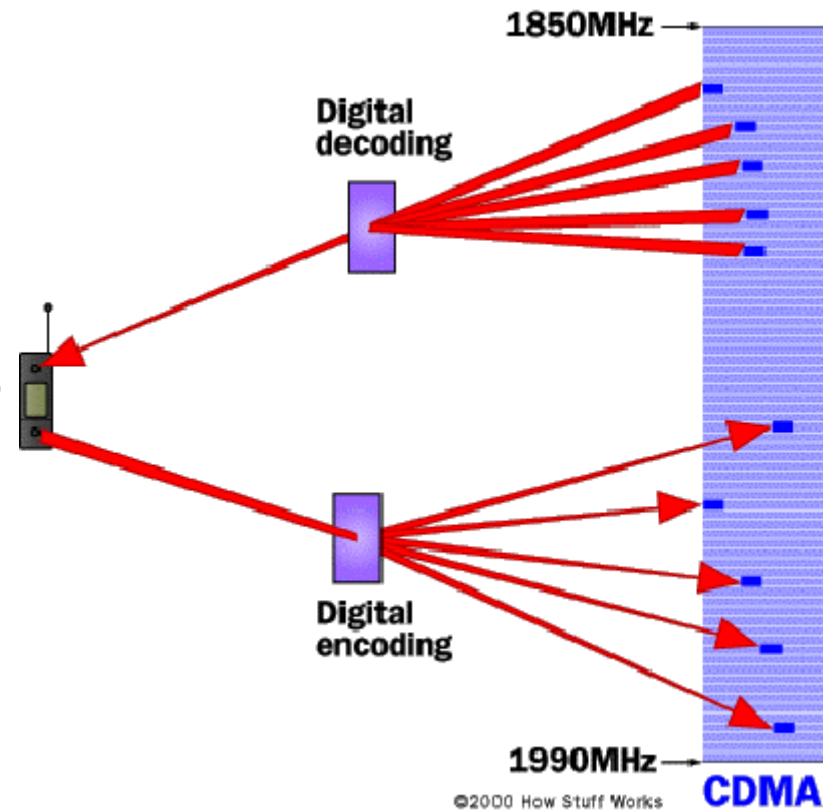
GSM

- Global System for Mobile communications
- TDMA
- Use encryption → security
- 900 MHz & 1800 MHz (Asia-Europe)
- 1900 MHz (US. – not compat. with above)
- International support → by changing Subscriber Identification Module (SIM) card



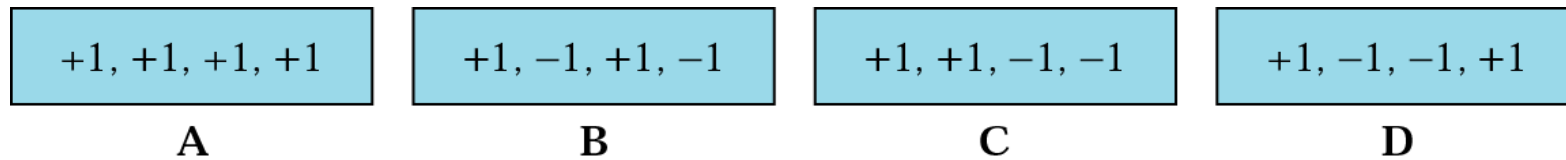
CDMA

- Spread spectrum
- Data → spread out
- Each call → unique sequence code
- Need accurate time stamp
- 800 MHz and 1900 MHz
- 8-10 times over Analog





CDMA



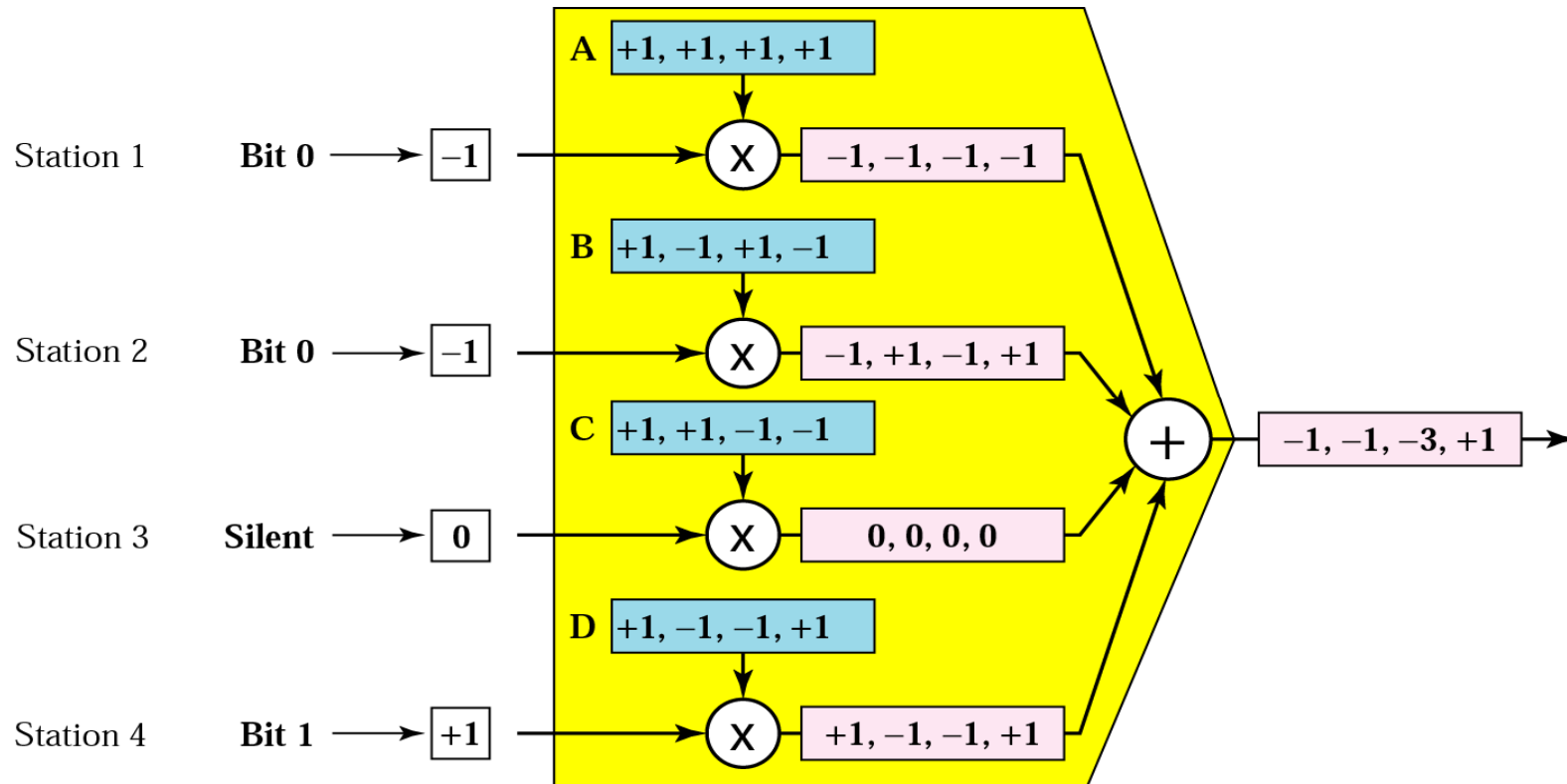
Chip sequence



Encoding rules

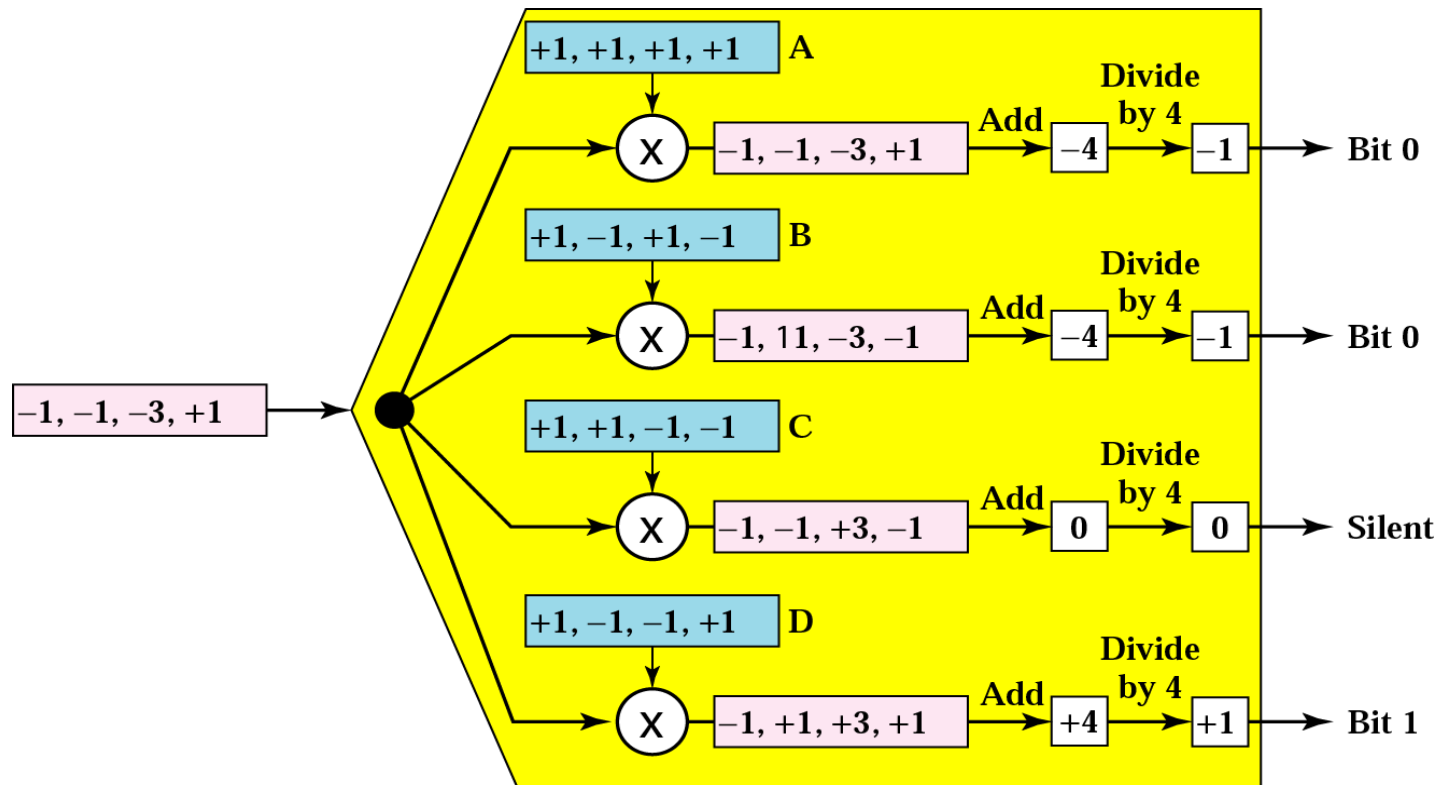


CDMA Multiplexer





CDMA Demultiplexer





Outline

- Wireless Classifications
- Wireless World (2G, 3G, ...)
- Basic Wireless Knowledge
 - Principles
 - Wireless Voice Communications
- **Wireless Data Communications**

Examples of Wireless Network Application



- Retail organization and Warehouses
 - Ordering, pricing, inventory, shipping
- Healthcare
 - Ensure the effective patient care record
- Field Service (Construction, Real Estate, Police, Disaster)
 - Mobile office (documentation access)

Examples of Wireless Network Application



- Hospitality
 - Reservation, check-in, status report
- Utilities / Vending
 - Automatic meter reading / maintenance / Stock



Wireless Network Applications

- Mobility needs
- Physical media is not feasible
- Eliminate paperwork
- Decrease errors
- Reduce process cost
- Improve efficiency



Wireless Network Benefits

- Mobility application support
- Lower network infrastructure cost

Mobility application characteristics



- Physically move while using an appliance
- Need real-time data access
 - Centralized database
- Applications that needs mobility
 - Immediately aware of data change
 - Immediately data availability
- Examples
 - Handheld devices in department store
 - Data acquisition in racing car

Reduce network infrastructure cost



- Release the tether
- Examples
 - **Installation**
 - **Reliability**
 - Decrease downtime
 - Mostly by cabling system
 - Imperfect spicing (unpredictable errors)
 - **Long term saving**
 - Reorganizing / renovation

Wireless Network Installation



- Installation in impossible to wire areas
 - Historical site
 - Digging the restriction area (road)
- Installation in difficult-to-wire areas
 - Rivers, freeway, obstacle building
- Health concern in the installation process
 - Asbestos working areas
- Installation time
 - Wiring period (cabling, digging, trenching)



Wireless Network Concerns

- Radio signal interference
- Power management
- System interoperability
- Network security
- Connection problems
- Installation issues
- Health risks



Radio signal interference

- Sources
 - Atmospheric noise
 - Nearby wireless devices
- Effects
 - Delay
 - Blocking
 - Bit errors
 - Limit the coverage area



Interference Types

- Inward interference
 - Interfered by others
 - Harmonics, microwave oven
- Outward interference
 - Causing interference to others
 - Adjacent WLAN

Interference reducing Techniques



- Limit operating power (< 1 watt)
- Spread spectrum Techniques
 - interference with signal-to-interference < 10 dB
- Frequency management
- Propagation test (site survey)



Power Management

- Tetherless to the electrical power outlet
- Battery (Weight & Operating time)
- Power management
 - Doze mode
radio off → periodically wakeup to check waiting msg.
 - Sleep mode
radio standby mode → wakeup to send, cannot receive



System interoperability

- Standard
 - protocols and electrical characteristics
- Current wireless standards
 - IEEE 802.11
 - HiperLAN
 - Bluetooth



Network Security

- Information protection
 - Loss
 - Corruption
 - Improper use
 - Interception (same NICs)
- Data flow in bit level
- Access restriction (access code)
- Data encryption (e.g., DES, AES algorithm)



Connection Problems

- Connection loss
 - Client / Server applications (TCP/IP)



Wireless Network Concerns

- Radio signal interference
- Power management
- System interoperability
- Network security
- Connection problems
- **Installation issues**
- Health risks



Health risks

- No conclusive answer
- Safer than cellular phone
 - 50 – 100 mW for WLAN
 - 600mW – 3 W for cellular phone
- Laser for public use

Wireless Network functionality



- Data transmission path
- Medium Access Control techniques
- Synchronization and error control
- Routing mechanism (source → destination)
- Appliance connectivity

Wireless Network Architecture



- Physical Architecture
 - Appliances (computer, PDA, printer)
 - Network software (Win2000 server)
 - Wireless Network Interface (NIC, modem)
 - Software driver (NDIS-Microsoft, ODI-Novell)
 - Antenna (Omni direction, Direction)
 - Communication channel (air, atmosphere, light)
- Logical Architecture
 - Network protocol (OSI)



Wireless (Data) Applications

- Mobility needs (Inventory)
- Physical media is not feasible (Factory)
- Eliminate paperwork (Car Rental)
- Decrease errors (Health care)
- Reduce process cost (Automatic Reading)
- Improve efficiency (Mobile Office)



Summary

- Wireless Classifications
- Wireless World (2G, 3G, ...)
- Basic Wireless Knowledge
 - Principles
 - Wireless Voice Communications
- Wireless Data Communications