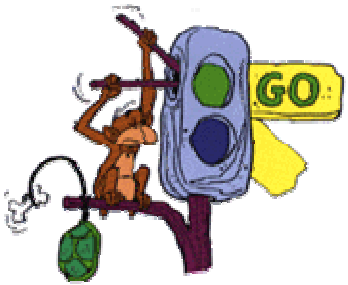
16.100 Introduction to Electrical and Computer Engineering
The Future of Wireless Communication



Jay Weitzen

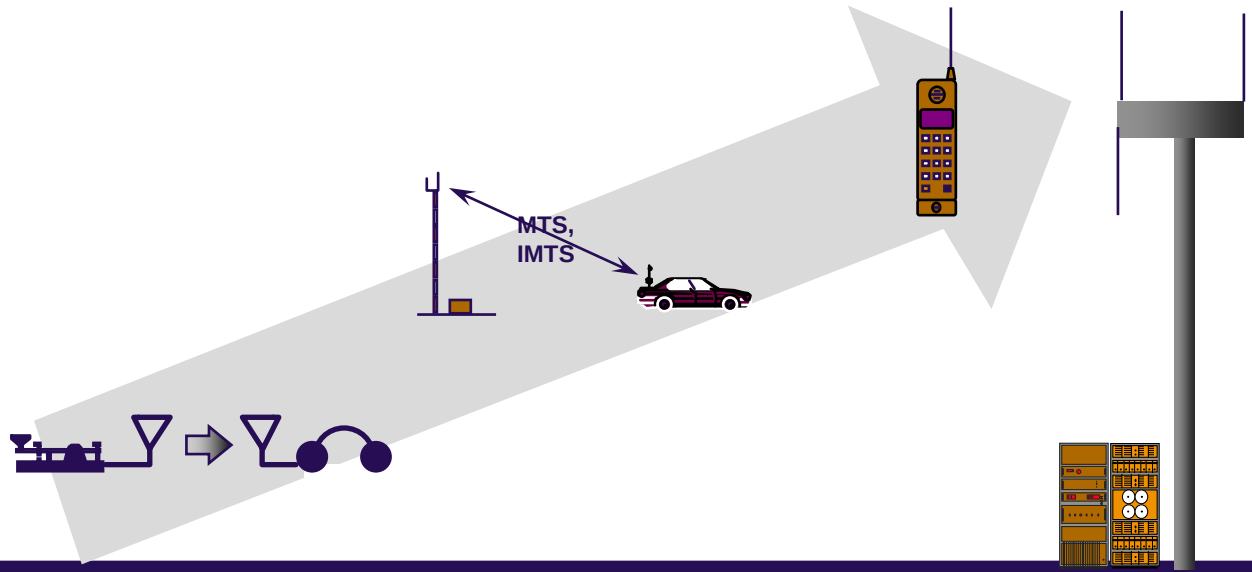
Professor Of Electrical And Computer Engineering

Umass Lowell ECE

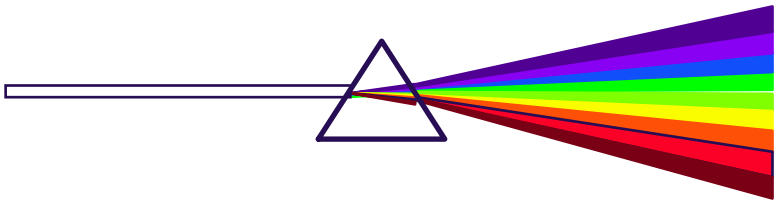
Talk Contents

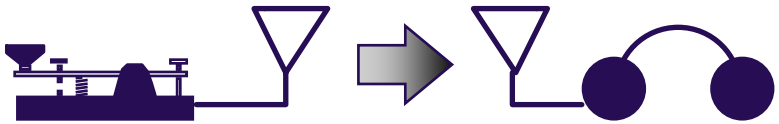
- A brief History of the North American Wireless System
- Generations of Wireless
- The Future of Wireless
- Demonstration of Cellular System Operation
- How To Prepare for A career in Wireless

A brief History of the Development of Wireless Communication



How Did We Get Here?



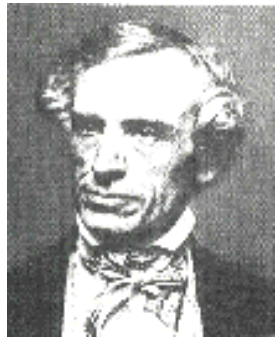


Days before radio.....

- **1680** Newton first suggested concept of spectrum, but for visible light only
- **1831** Faraday demonstrated that light, electricity, and magnetism are related
- **1864** Maxwell's Equations: spectrum includes more than light
- **1890's** First successful demos of radio transmission

Telegraphy

- Samuel F.B. Morse had the idea of the telegraph on a sea cruise in the 1833. He studied physics for two years, and In 1835 demonstrated a working prototype, which he patented in 1837.
- Derivatives of Morse' binary code are still in use today
- The US Congress funded a demonstration line from Washington to Baltimore, completed in 1844.
- 1844: the first commercial telegraph circuits were coming into use. The railroads soon were using them for train dispatching, and the Western Union company resold idle time on railroad circuits for public telegrams, nationwide
- 1857: first trans-Atlantic submarine cable was installed



Samuel F. B. Morse
at the peak of his career

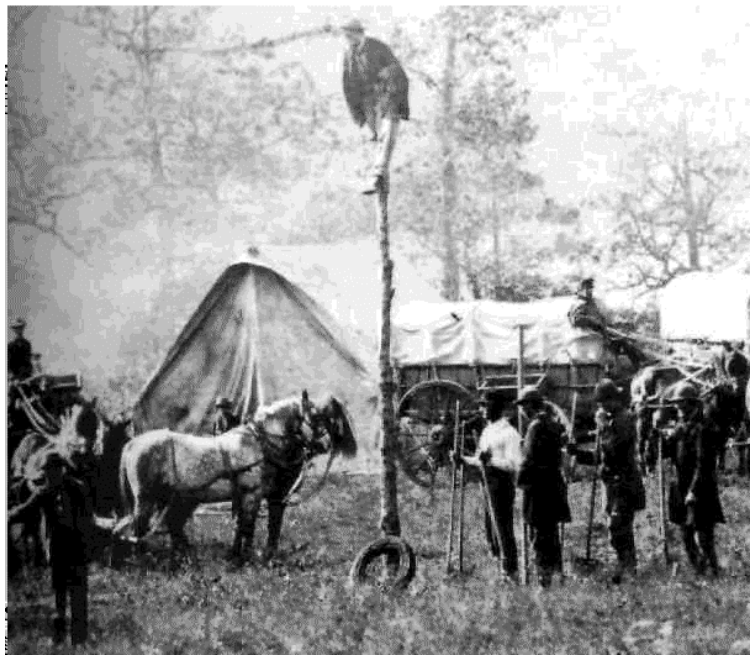
Submarine Cable Installation
news sketch from the 1850's

Field Telegraphy
during the US Civil War, 1860's

Telephony

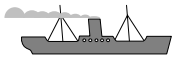
- By the 1870's, the telegraph was in use all over the world and largely taken for granted by the public, government, and business.
- In 1876, Alexander Graham Bell patented his telephone, a device for carrying actual voices over wires.
- Initial telephone demonstrations sparked intense public interest and by the late 1890's, telephone service was available in most towns and cities across the USA

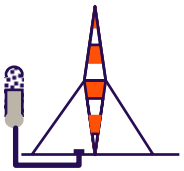
Alexander Graham Bell and his phone
from 1876 demonstration



Telephone Line Installation Crew

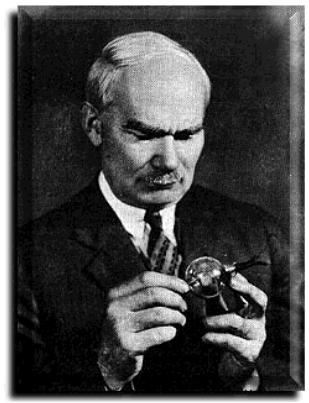
Radio Milestones





- 1888: Heinrich Hertz, German physicist, gives lab demo of existance of electromagnetic waves at radio frequencies
- 1895: Guglielmo Marconi demonstrates a wireless radio telegraph over a 3-km path near his home it Italy
- 1897: the British fund Marconi's development of reliable radio telegraphy over ranges of 100 kM
- 1902: Marconi's successful trans-Atlantic demonstration
- 1902: Nathan Stubblefield demonstrates voice over radio
- 1906: Lee De Forest invents "audion", triode vacuum tube
  - feasible now to make steady carriers, and to amplify signals
- 1914: Radio became valuable military tool in World War I
- 1920s: Radio used for commercial broadcasting
- 1940s: first application of RADAR - English detection of incoming German planes during WW II
- 1950s: first public marriage of radio and telephony - MTS, Mobile Telephone System
- 1961: transistor developed: portable radio now practical
- 1961: IMTS - Improved Mobile Telephone Service
- 1970s: Integrated circuit progress: MSI, LSI, VLSI, ASICs
- 1979, 1983: AMPS cellular demo, commercial deployment

Guglielmo Marconi
radio pioneer, 1895



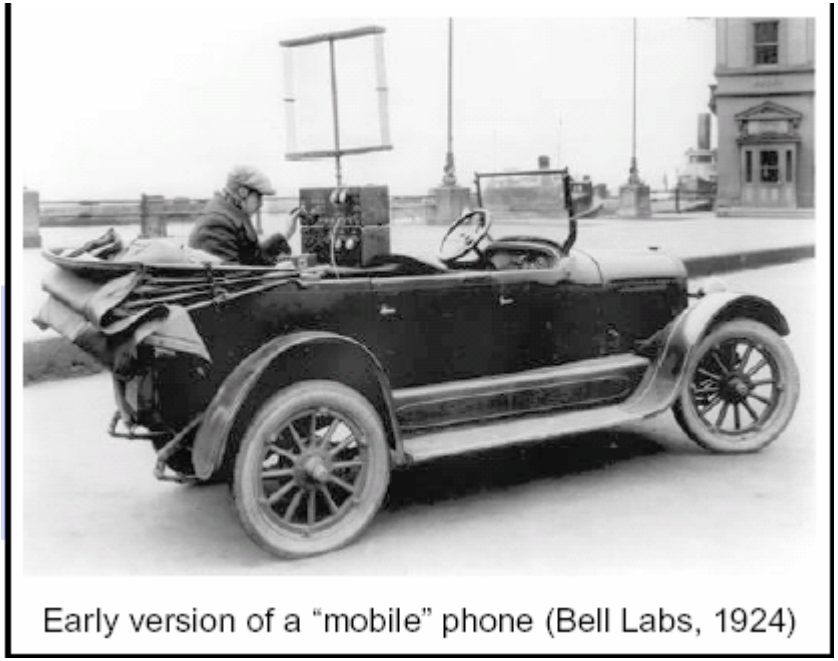
Lee De Forest
vacuum tube inventor

Generations of Wireless

- First Generation, Analog Circuit Switched Voice, Analog Modem/Fax over Circuit Switched Voice
  - AMPS
- 2nd Generation: Digital Vocoded Circuit Switched Voice, Circuit Switched data 16-64 kbps
  - IS-95 A&B, IS-136, GSM (GPRS), IDEN
  - 2.5G low rate packet data comes to wireless (GPRS, EDGE)
- 3rd Generation, Digital Circuit Switched Voice, Packet Switched Broadband Data
  - CDMA 2000 (IS-95C 1xRTT)+ 1xEV-DO, WCDMA (UMTS)
  - 3.5 G, VOIP and QOS come to wireless
- 4th Generation, Broadband Packet Switched Voice (VOIP), Broadband Packet Switched Data MBPS, Fixed Mobile Convergence
  - IEEE 802.16e (wimax), IEEE 802.20, EV-DO Rev C (UMB), LTE,

Early Wireless systems

Wireless Telephone Set (Marconi, 1920)



Early version of a “mobile” phone (Bell Labs, 1924)

History of Mobile Phones

"B-Netz" car phone
(Bosch, 1976) / weight: 13.5 kg

"C-Netz" car phone
(Bosch, 1988) / weight: 5 kg

"C-Netz" mobile phone
(Philips, 1992)
weight: 0.6 kg

History of Mobile Phones (cont'd)

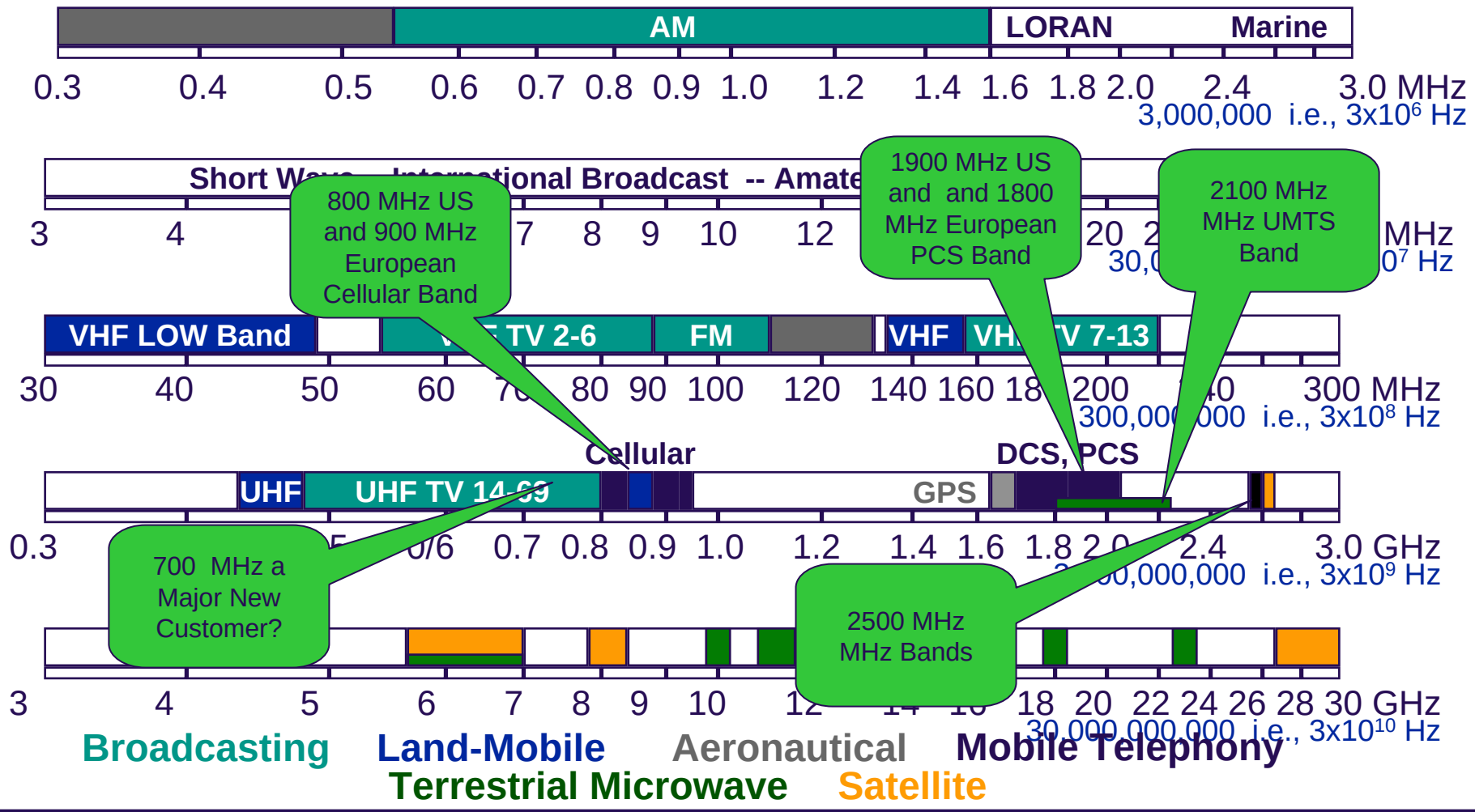
GSM phone (Sewon, 2002)
68 X 38.5 X 22 mm
weight: 72 g

DECT phone
(Siemens, 2002)
weight: 100 g

UMTS mobile phone
(Sony-Ericsson, 2003)

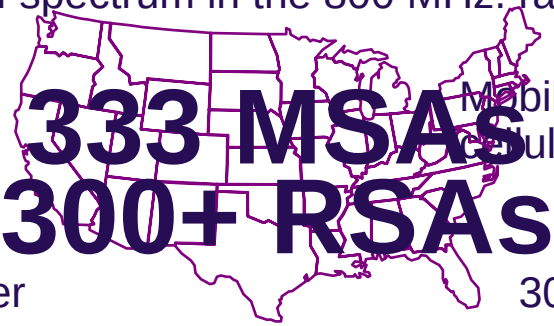
2007 IPHONE

Frequencies Used by Wireless Systems



Development of North American Cellular

- In the late 1970's, the FCC (USA Federal Communications Commission) and the Canadian government allocated 40 MHz. of spectrum in the 800 MHz. range for public mobile telephony.
- FCC adopted Bell Lab's AMPS (Advanced Mobile Phone System) standard, creating cellular as we know it today
  - The USA was divided into 333 MSAs (Metropolitan Service Areas) and over 300 RSAs (Rural Service Areas)
- By 1990, all MSAs and RSAs had competing licenses granted and at least one system operating. Canadian markets also developed.
- In 1987, the FCC allocated 10 MHz. of expanded spectrum
- In the 1990's, additional technologies were developed for cellular
  - TDMA (IS-54,55,56, IS-136) (also, GSM in Europe/worldwide)
  - CDMA (IS-95)
- US Operators did not pay for their spectrum, although processing fees (typically $10,000's) were charged to cover license administrative cost



North American Cellular Spectrum

Ownership and Licensing

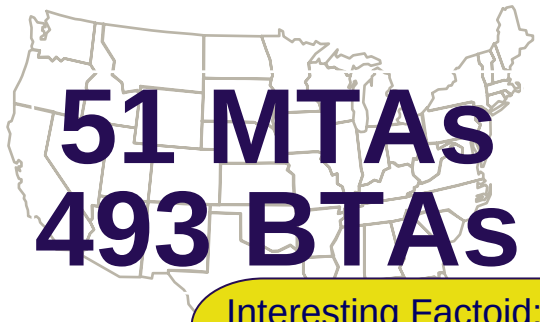
Frequencies used by "A" Cellular Operator
Initial ownership by Non-Wireline companies

Frequencies used by "B" Cellular Operator
Initial ownership by Wireline companies

- In each MSA and RSA, eligibility for ownership was restricted
  - "A" licenses awarded to non-telephone-company applicants only
  - "B" licenses awarded to existing telephone companies only
  - subsequent sales are unrestricted after system in actual operation

Development of North America PCS

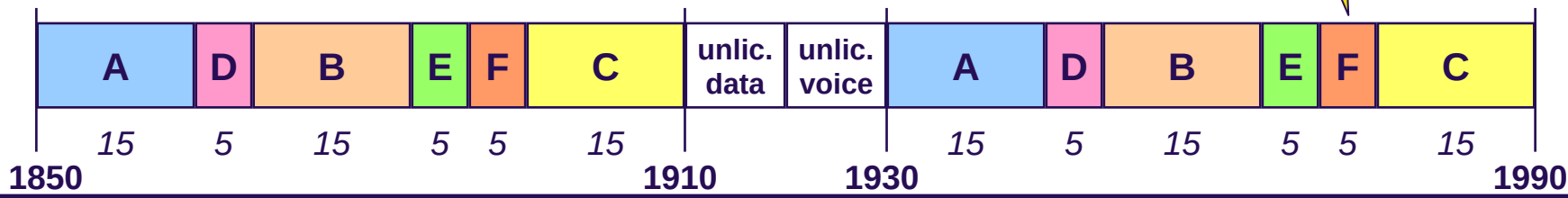
- By 1994, US cellular systems were seriously overloaded and looking for capacity relief
  - The FCC allocated 120 MHz. of spectrum around 1900 MHz. for new wireless telephony known as PCS (Personal Communications Systems), and 20 MHz. for unlicensed services
  - allocation was divided into 6 blocks; 10-year licenses were auctioned to highest bidders



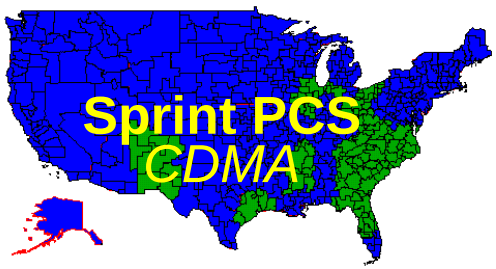
Interesting Factoid: Charlie Dolan Uses this License as Collateral to try to Purchase Boston Red Sox

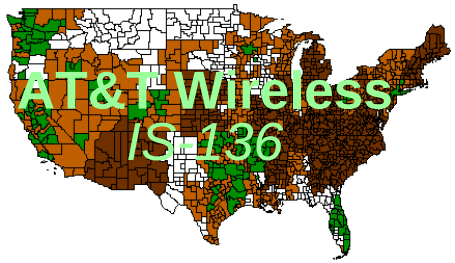
- PCS Licensing and Auction Details
  - A & B spectrum blocks licensed in 51 **MTAs** (Major Trading Are
    - Revenue from auction: $7.2 billion (1995)
  - C, D, E, F blocks were licensed in 493 **BTAs** (Basic Trading Ar
    - C-block auction revenue: $10.2 B, D-E-F block auction: $2+ B 6)
  - Auction winners are free to choose any desired technology

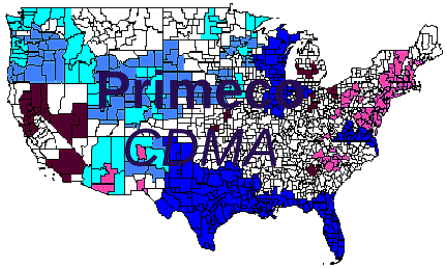
PCS SPECTRUM ALLOCATIONS IN NORTH AMERICA

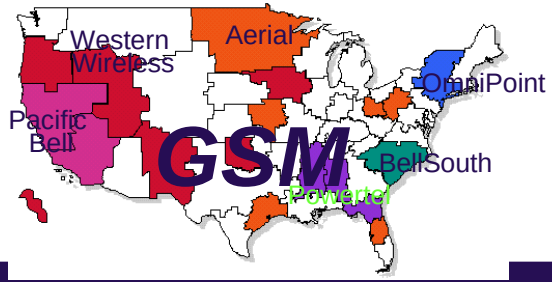


Major PCS North American Carriers









The Largest Players, Areas, and Technologies

- **Sprint PCS**
  - Partnership of Sprint, TCI, Cox Cable
  - Bid & won in 2/3 of US markets A or B blocks
  - Sprint itself has D and/or E blocks in remaining markets
  - **CDMA**: Mix of Nortel, Lucent, Motorola
  - Merged with Nextel, whose 900 MHz network will be integrated into Sprint network beginning late 2007
- **AT&T Wireless Systems (merged with Cingular)**
  - Bid & won a majority of markets in A&B Blocks
  - will combine and integrate service between its new PCS 1900 systems and its former McCaw cellular 800 MHz. properties
  - **IS-136**: mix of Lucent and Ericsson equipment
  - **GSM/UMTS** conversion underway
- **Verizon**
  - Formed from merger of of Airtouch, US West, Bell Atlantic, NyNex and GTE
  - **CDMA**: Mix of Motorola, Nortel, and Lucent networks
- **GSM Alliance (became T-Mobile)**
  - Western Wireless, OmniPoint, BellSouth, Powertel, Pacific Bell
  - Mix of Ericsson, Nokia, and Nortel networks

US PCS Bands

C-Block License sells for $562M in boston

Block Designator	Allocated	Mobile xmit Frequency	Base xmit
A (mta)	30 (15/15)	1850-1865	1930-1945
D (bta)	10 (5/5)	1865-1870	1945-1950
B (MTA)	30 (15/15)	1870-1885	1950-1965
E (bta)	10 (5/5)	1885-1890	1965-1970
F (bta)	10 (5/5)	1890-1895	1970-1975
C (bta)	30 (15/15)	1895-1910	1975-1990

In Boston: ATT/GSM UMTS

In Boston: T-Mobile /GSM UMTS

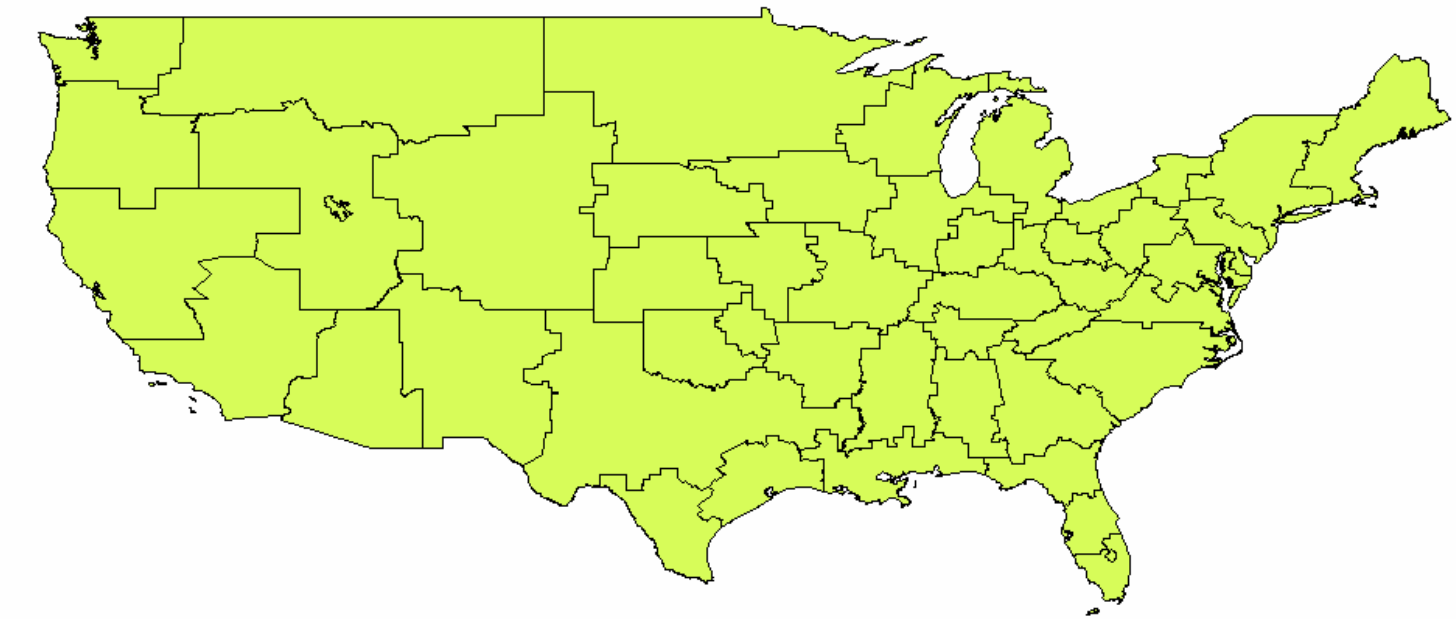
In Boston: Sprint

In Boston: T-Mobile /GSM UMTS?

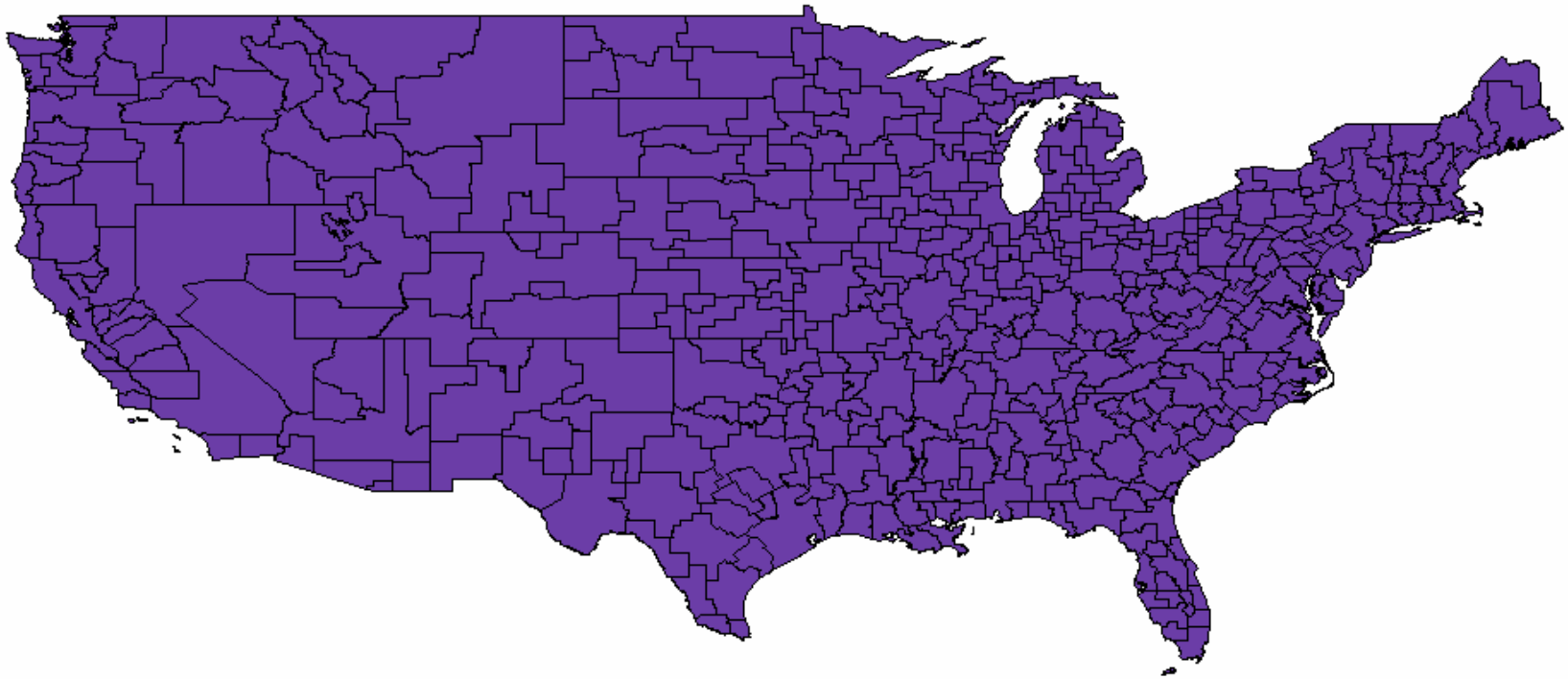
In Boston: Cingular, VzW

In Boston: Verizon/1xevdo

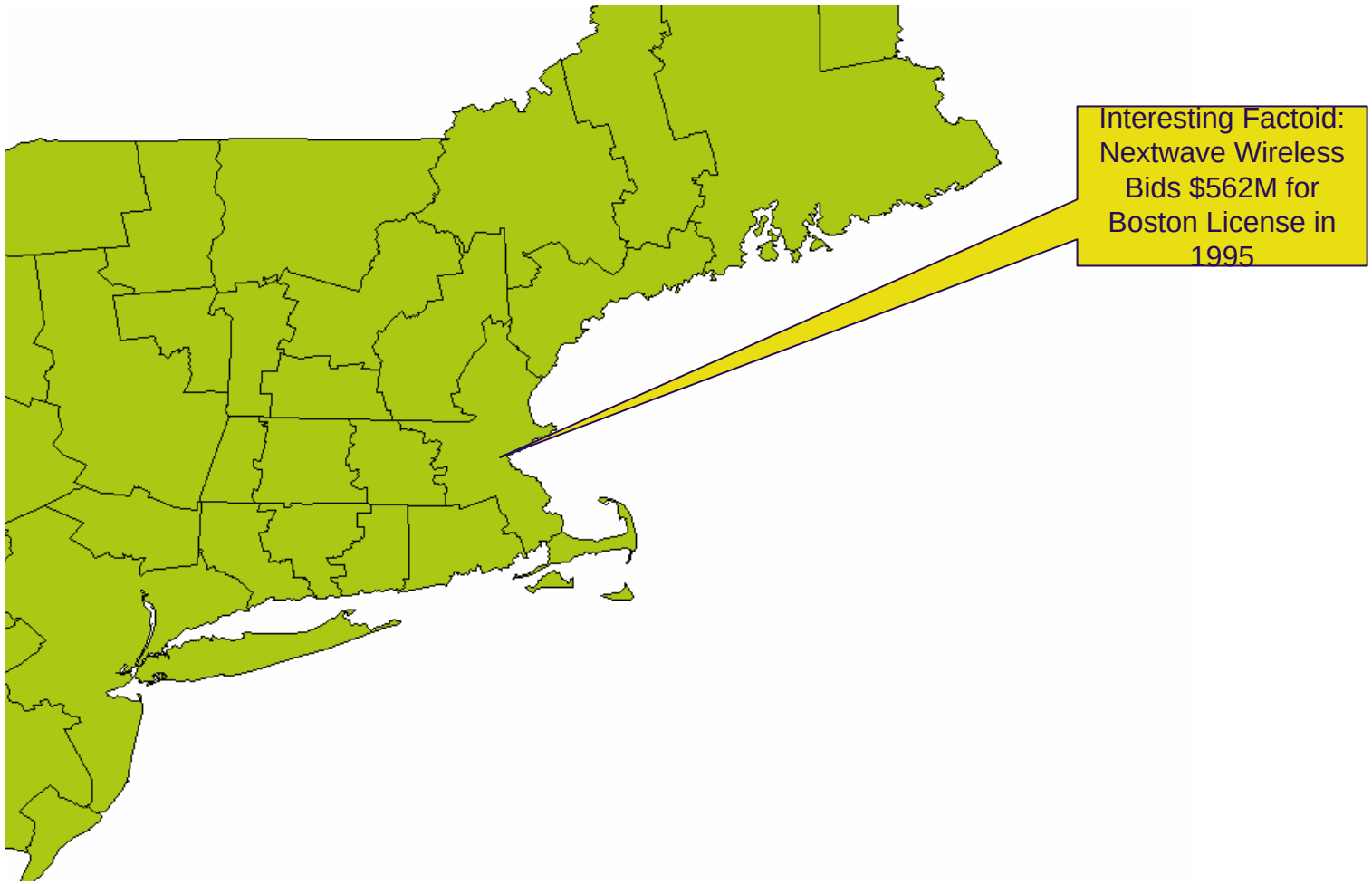
US-MTA's



US-BTA's



NE BTA's


Interesting Factoid:
Nextwave Wireless
Bids $562M for
Boston License in
1995

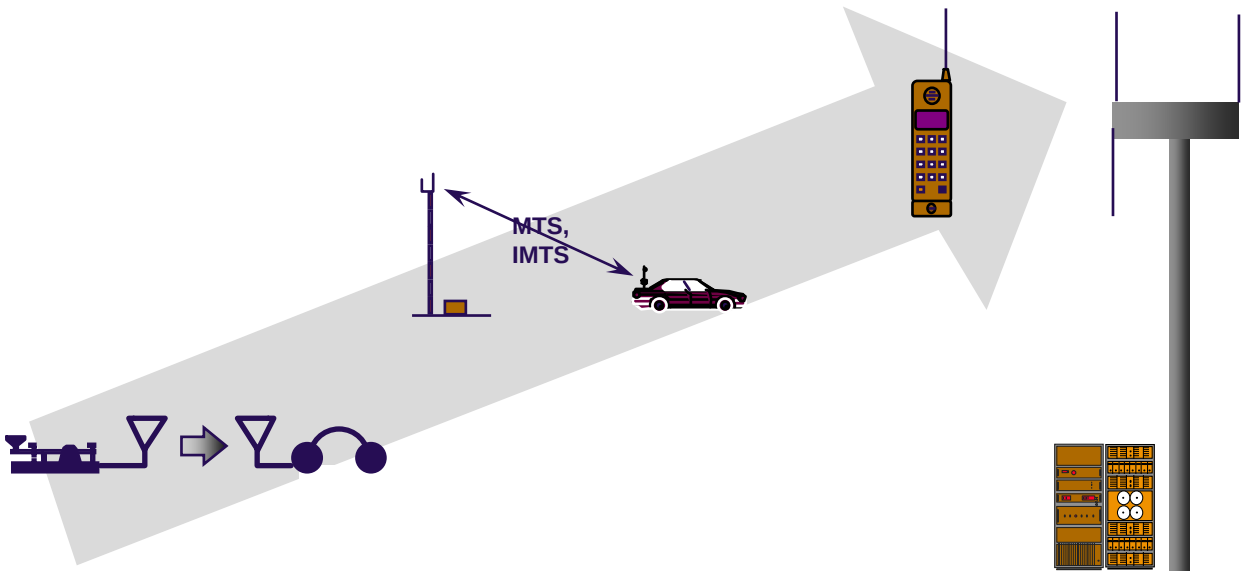
Consolidation in the Wireless Industry: 4 major players + 3 Regional

- Verizon: Formed from Bell Atlantic Mobile (which formed from NYTel and NETel), GTE Mobilenet, PrimeCo ,and AirTouch Mobile (CDMA)
- ATT/Cingular (GSM, UMTS, IS-136)
- Sprint/Nextel (CDMA/Iden)
- T-Mobile (absorbed most of “gsm alliance” including VoiceStream, Omnipoint, and Western Wireless)

Consolidation in Wireless Industry (cont'd)

- 2nd Tier Regional Carriers
  - US cellular
  - Leap
  - Alltel

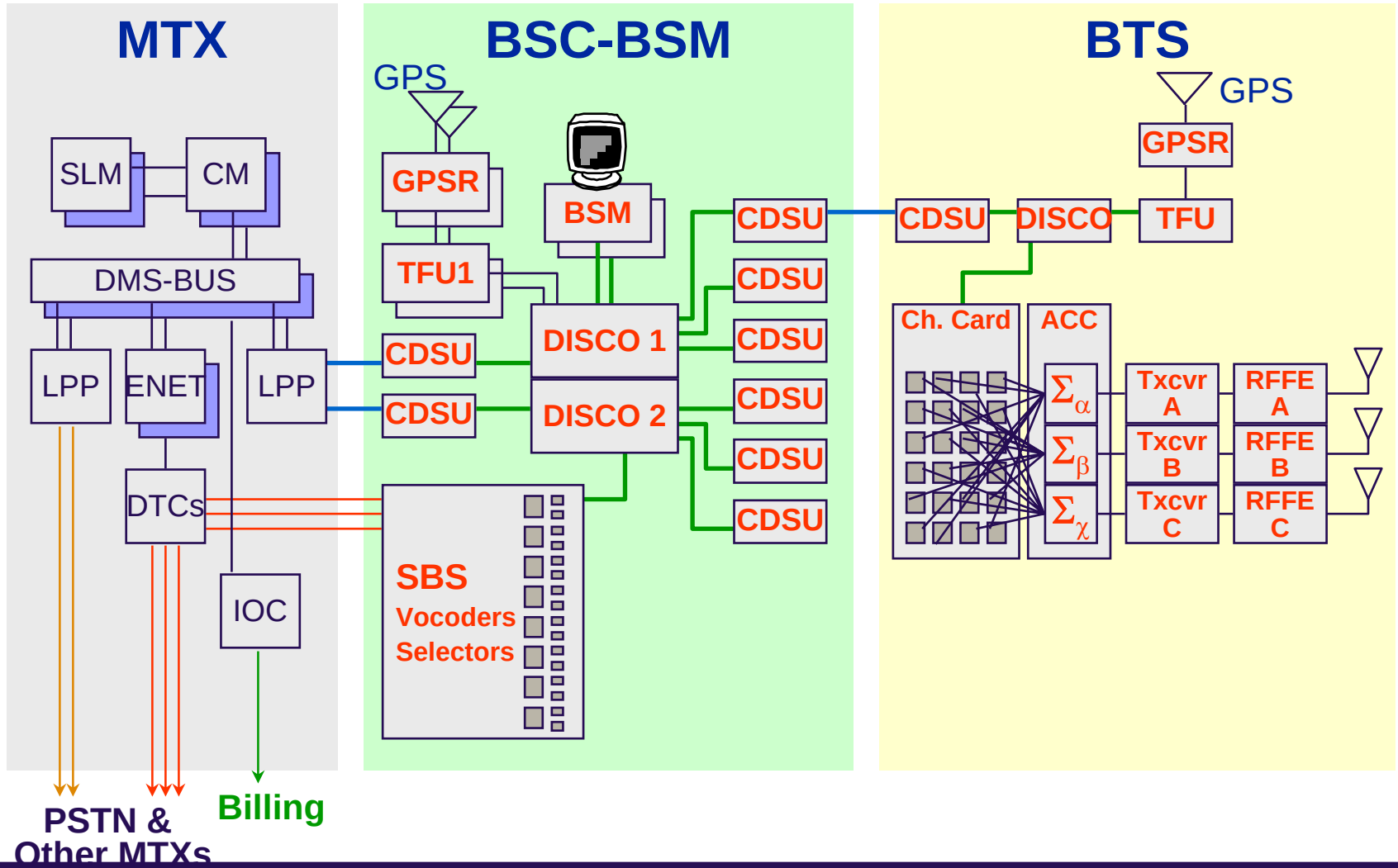
What Makes Up A Modern Wireless Network?



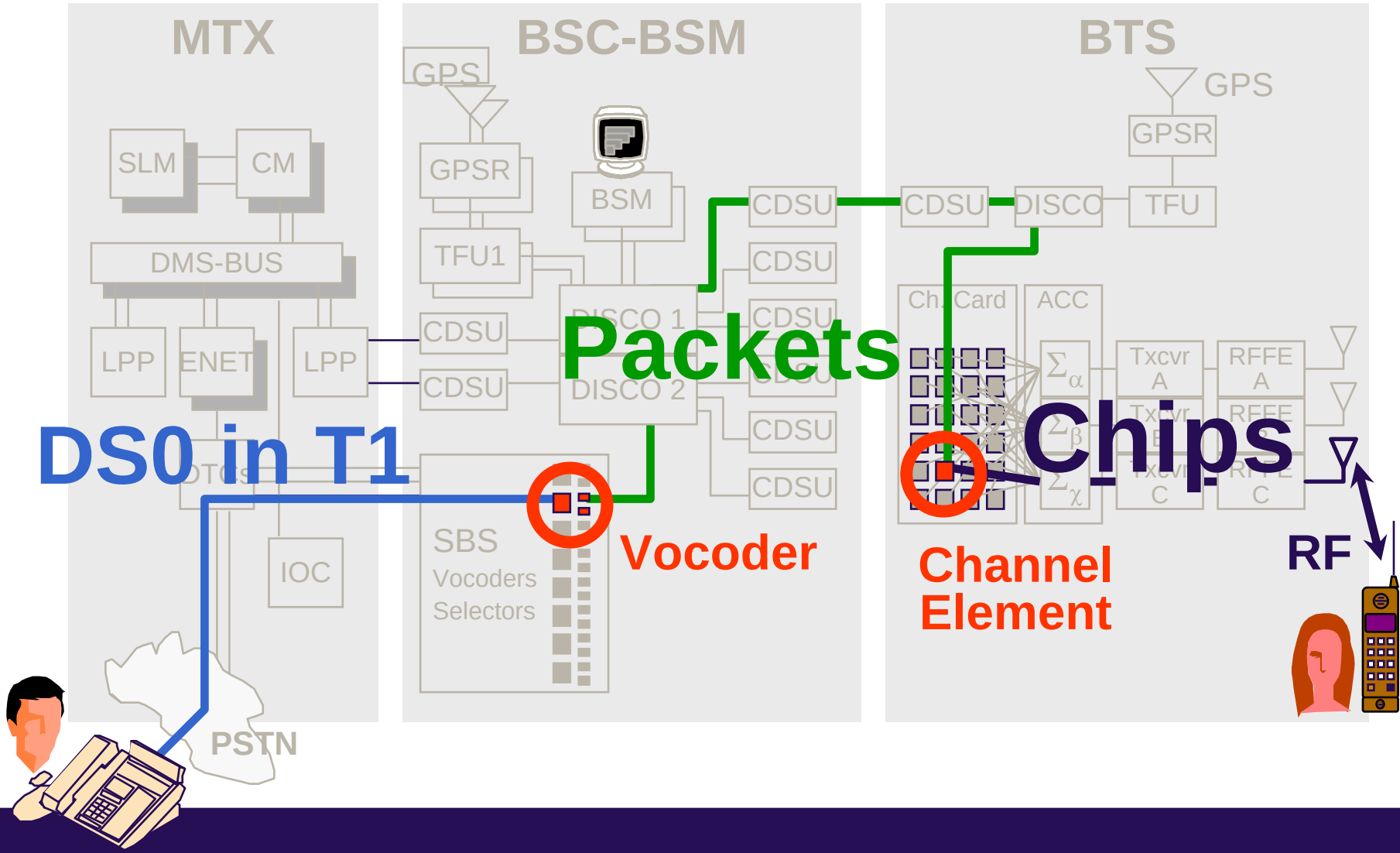
Major Elements of A Wireless System

- Mobile Terminal
- Access Point (a.k.a. Base station, bts)
- Mobility Manager (a.k.a. BSC, RNC)
- Service Termination Point (MSC, PDSN/SGSN)

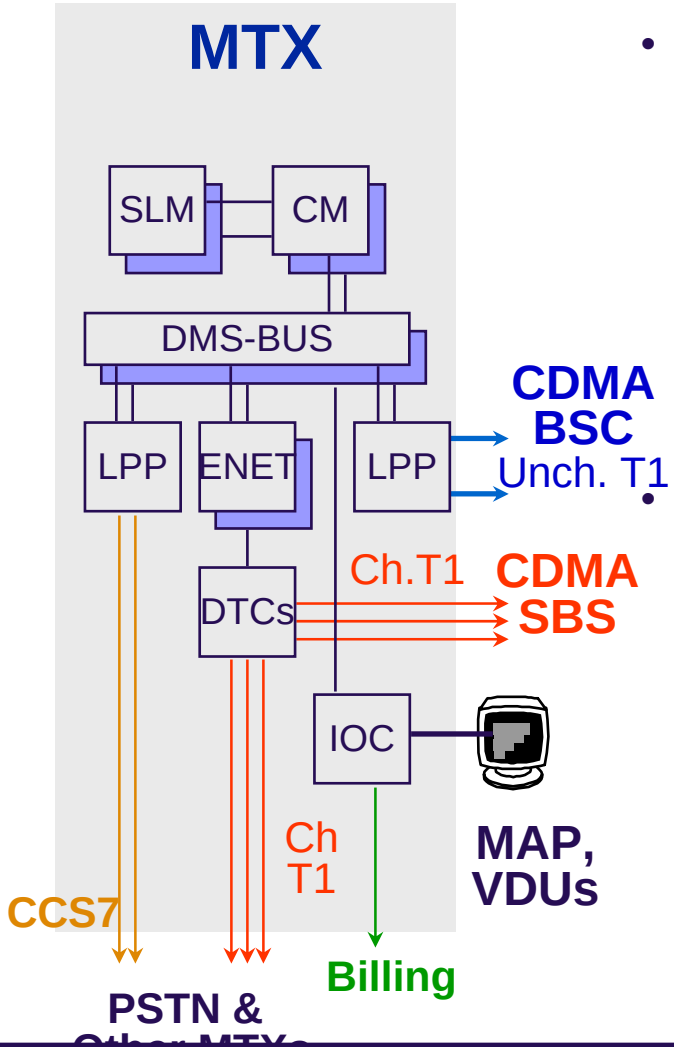
Example: NORTEL CDMA System Architecture



Signal Flow: Two-Stage Metamorphosis

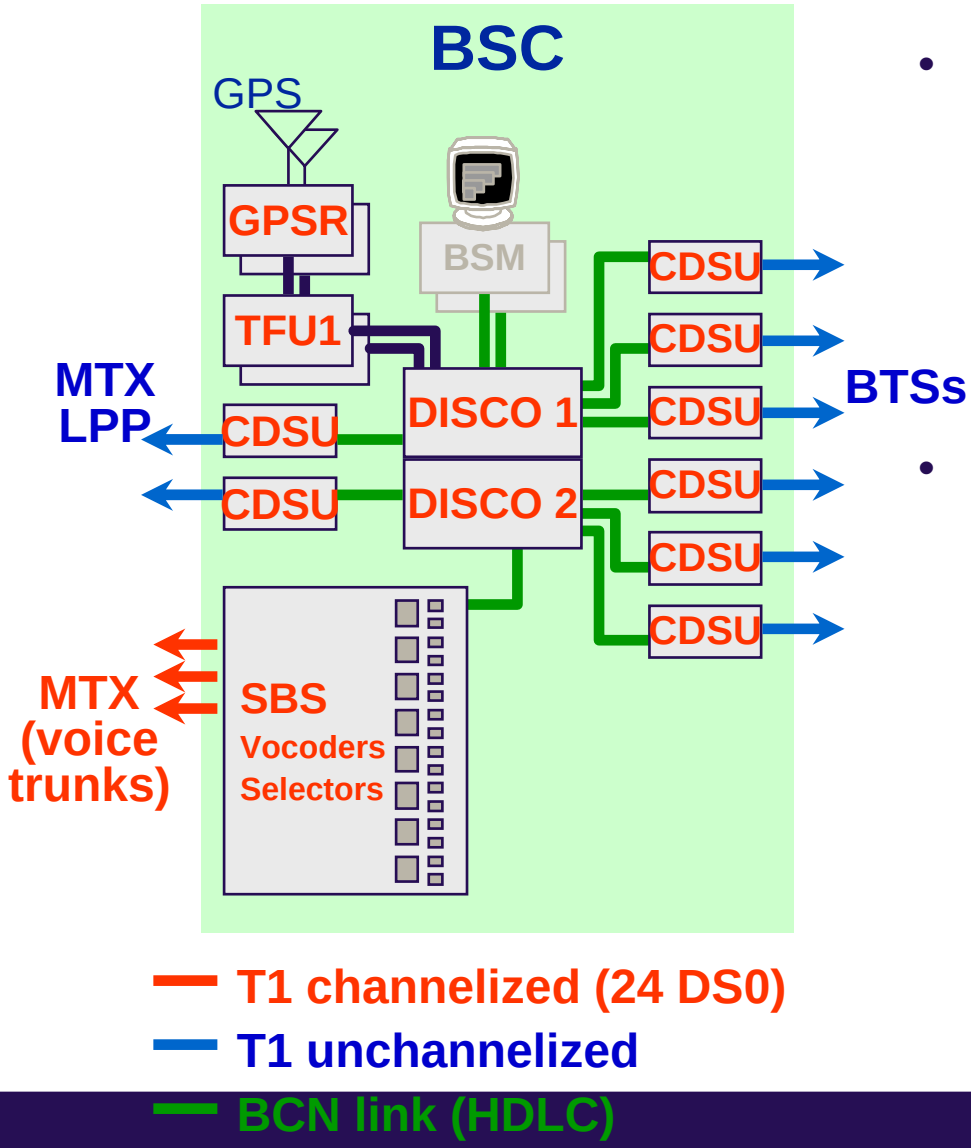


Architecture: The MTX



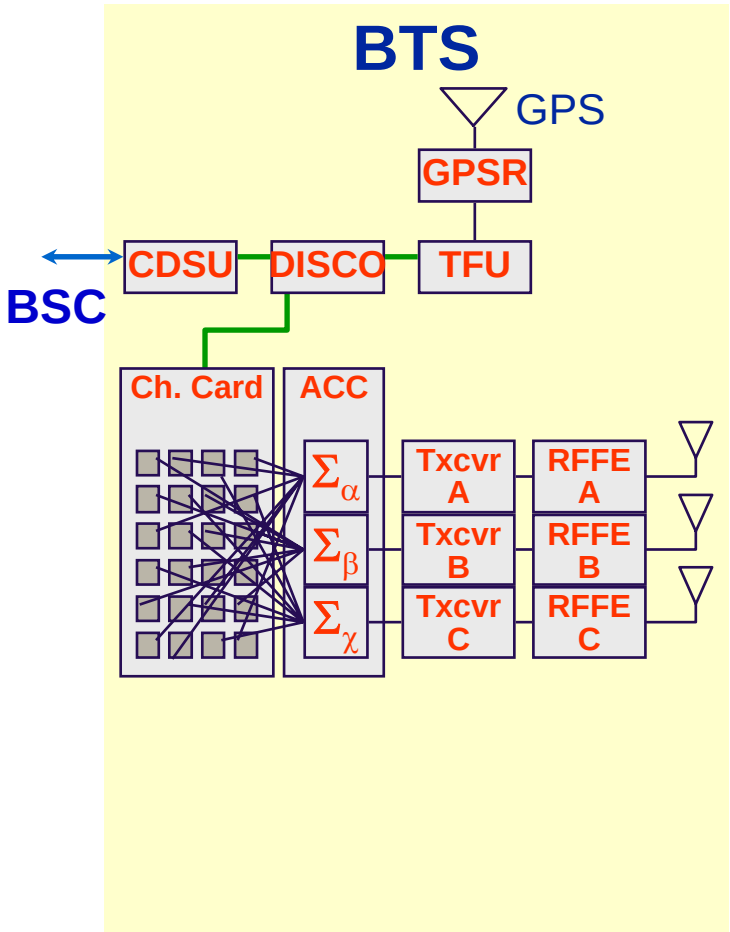
- Primary functions
  - HLR-VLR access
  - Intersystem call delivery (IS-41C)
  - Inter-MTX handover (IS-41C)
  - Billing Data Capture
  - Calling Features & Services
  - Collecting System OMs, Pegs
- High reliability, redundancy

Architecture: The BSC



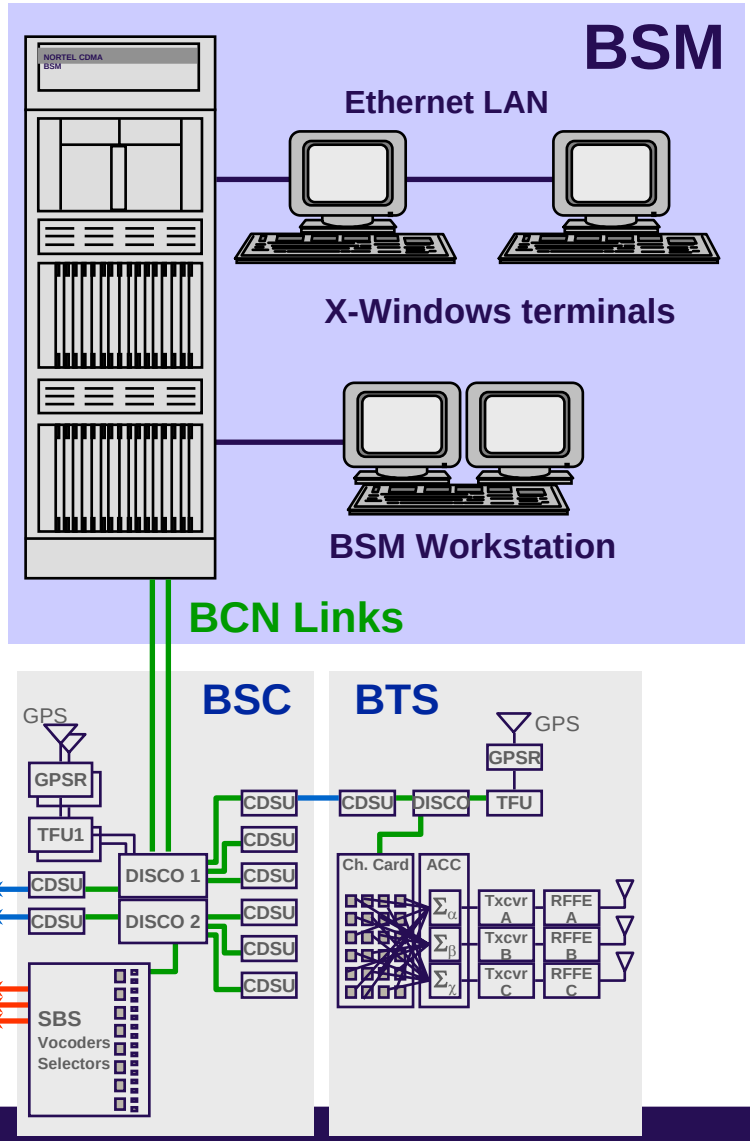
- Primary functions
  - vocoding
  - soft handoff management
  - FER-based power control
  - routing of all traffic and control packets
- Scaleable architecture
  - expand SBS to keep pace with traffic growth

Architecture: The BTS



- Primary function: Air link
  - generate, radiate, receive CDMA RF signal IS-95/J.Std. 8
  - high-efficiency T1 backhaul
  - test capabilities
- Configurations
  - 1, 2, or 3 sectors
  - 800 MHz.: indoor
  - 1900 MHz.: self-contained outdoor, remotable RFFEs
  - future: 1900 MHz. indoor, 800 & 1900 multi-carrier options

Architecture: The BSM

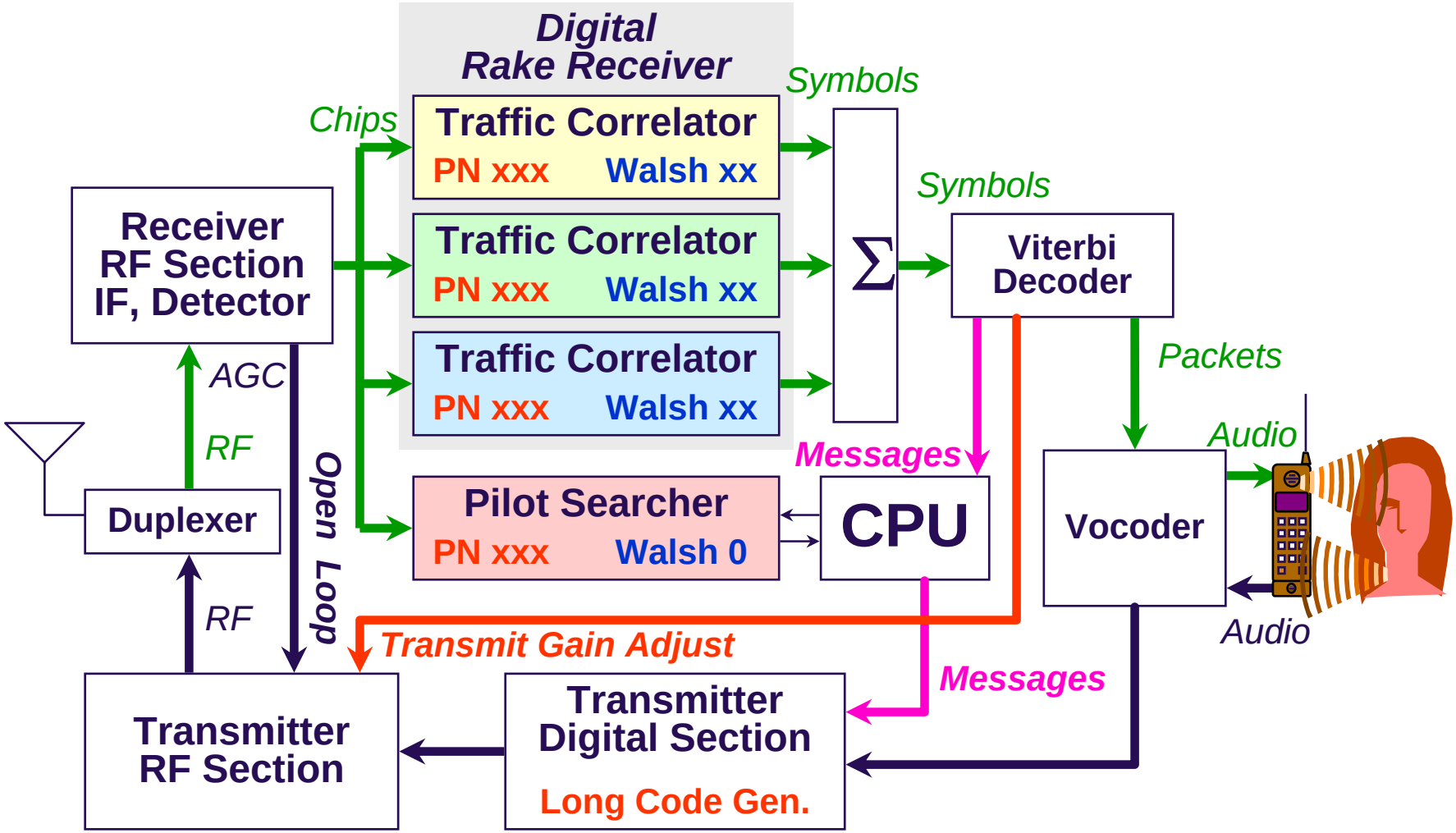


- Primary functions: OA&M for CDMA components
  - Configuration management
    - BSC, BTS configuration and parameters
  - Fault management
    - Alarm Reporting
  - Performance management
    - interface for CDMA statistics and peg counts collection
  - Security management
  - Unix-based

Mobile Terminal

- Also called Access Terminal (AT, data card, phone, PDA, etc)
- Transceiver (rx and tx)
- User Interface (keyboard and display)
- Implement UE airlink protocols
- Terminate the Application layer protocol

What's In a Handset?



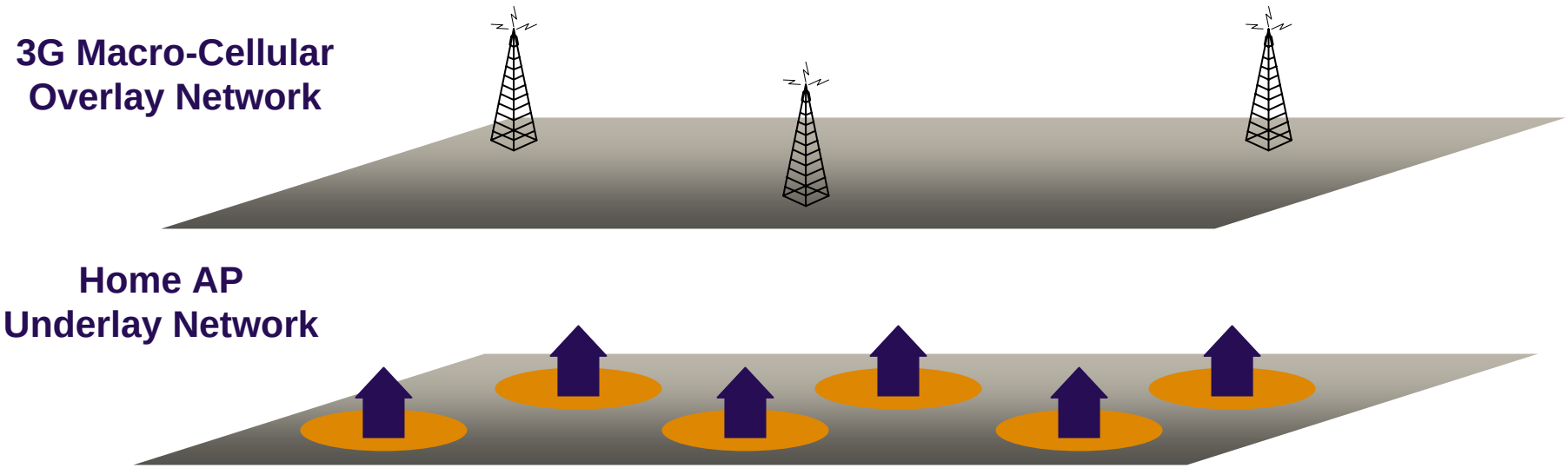
BTS/AP Functions

- Implement the Airlink protocol (e.g. wifi, wcdma,cdma-2000)
- Communicate with the mobility management system (e.g. BSC/RNC)
- Provide OA&M data

The Future of Wireless Coming to you!

- QOS Enabled Services Over wireless
  - Next Generation Push to Talk Services
  - Video Telephony
  - Interactive Gaming between Cell Phones
  - Voice Over IP
- Fixed Mobile Convergence
  - Wifi/Personal BTS at home, Macro Cellular Network

Fixed Mobile Convergence



- Overlay network – Outdoor coverage & mobility. Operator bears cap-ex and op-ex
- Underlay network – Inbuilding coverage. Consumer shares cap-ex and op-ex

Femto Cells and FMC

3GPP2 Compliant PDIF – Security Gateway and Mobile IP Foreign Agent

Picasso CDMA Femto Cell
1xRTT & EVDO. 6 Users.
Integrated BSC/RNC/PDSN

DSL, Cable, Fiber IP Network

Existing handset

- **Service Activation**
- **Network Planning**
- **TR-069 Device Management**

Picasso Service Manager
Activation, Provisioning & Remote Management

Value Proposition

- ***Creates home phone service***
- ***Superior user experience***
- ***Off-loads macro network***

Emerging Careers in Wireless

- Each box in the new architecture
- Wireless Service Providers (can you hear me)
- Applications Development
- For more Information
  - Jay Weitzen, Ball 411
  - Jay_weitzen@uml.edu

Preparing for Future Careers in Wireless

- Basic Courses:
  - 16.362 (signals and systems)
  - 16.363 (probability and random signals)
  - 16.460 (electromagnetics)
- Elective/Advanced courses
  - Wireless Communication
  - Communication Theory
  - Antenna Design
  - RF Design

YABBA DABBA DOO!
Thank You for Attending