A Technical Introduction to Wireless

Topics

Introduction to Wireless

Modulation, signal science

CDMA, TDMA, GSM, capacity

Propagation

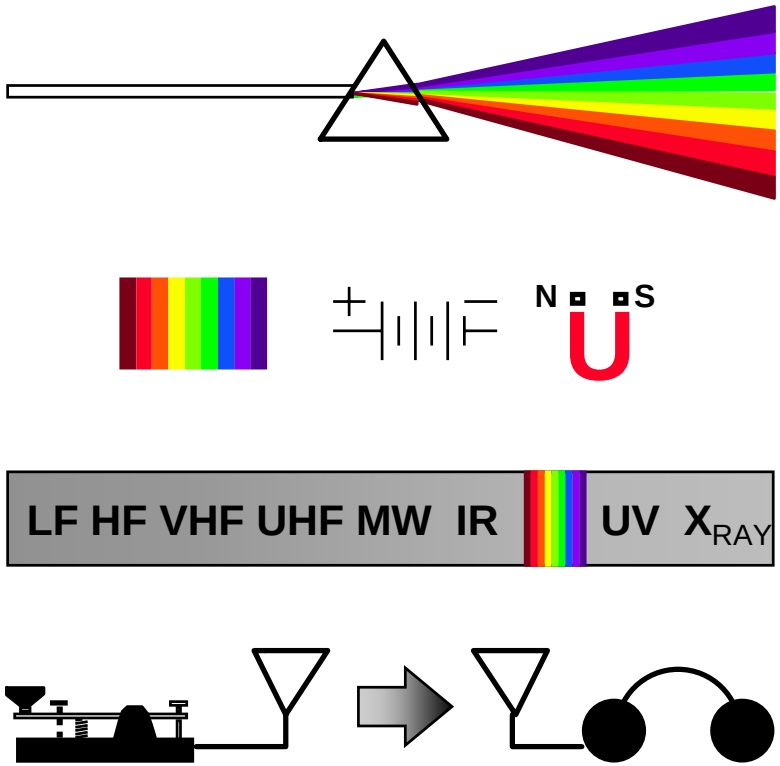
Antennas

Traffic Engineering

CDMA

Special Topics

How Did We Get Here?

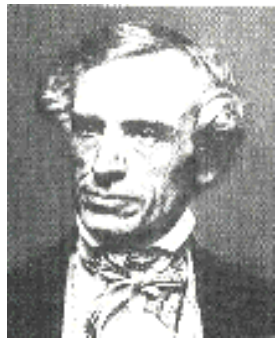


Days before radio.....

- **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

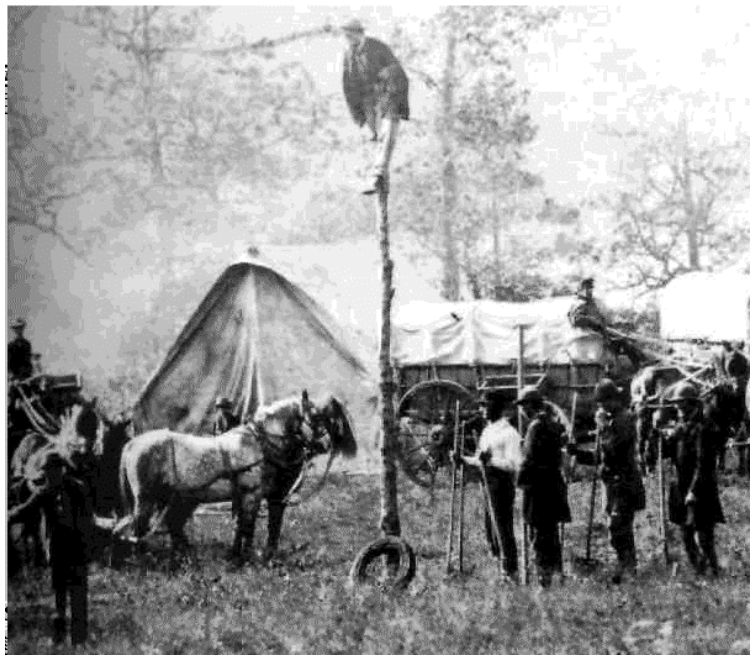
Submarine Cable Installation
news sketch from the 1850's

Field Telegraphy
during the US Civil War, 1860's

Telephony

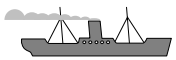
- By the 1870's, the telegraph was in use all over the world and largely taken for granted by the public, government, and business.
- In 1876, Alexander Graham Bell patented his telephone, a device for carrying actual voices over wires.
- Initial telephone demonstrations sparked intense public interest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

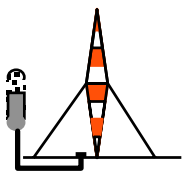
Alexander Graham Bell and his phone
from 1876 demonstration

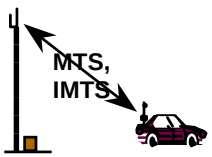


Telephone Line Installation Crew
1880's

Radio Milestones

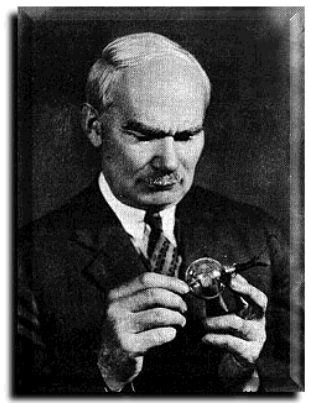






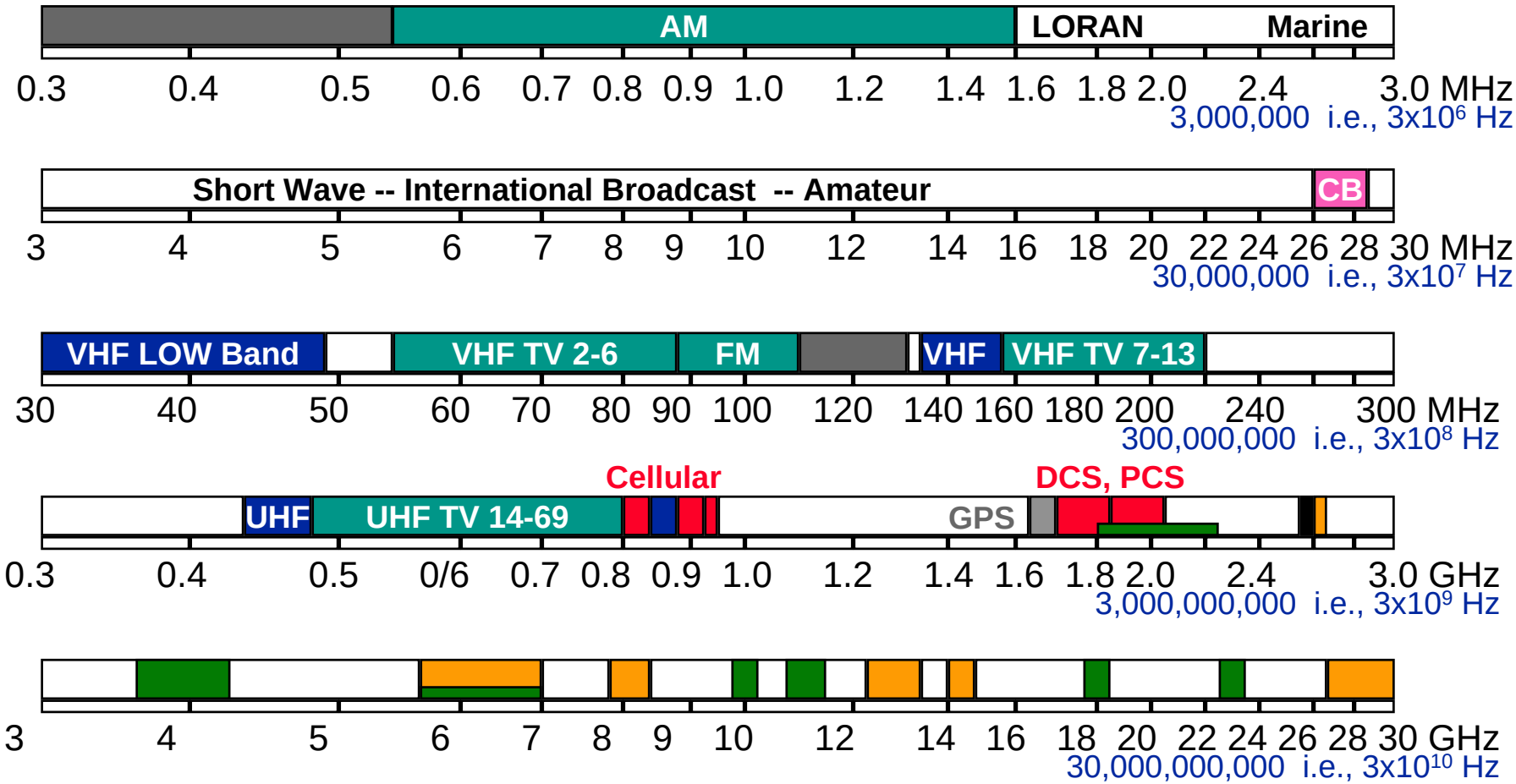
- 1888: Heinrich Hertz, German physicist, gives lab demo of existance of electromagnetic waves at radio frequencies
- 1895: Guglielmo Marconi demonstrates a wireless radio telegraph over a 3-km path near his home it Italy
- 1897: the British fund Marconi's development of reliable radio telegraphy over 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



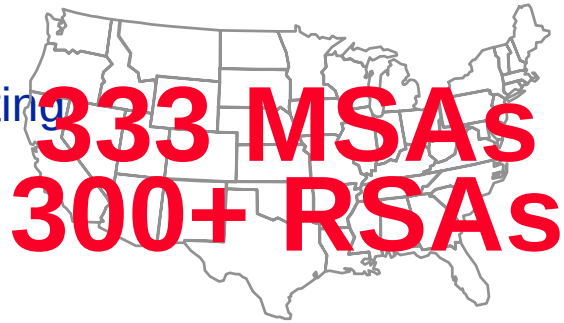
Lee De Forest
vacuum tube inventor

Frequencies Used by Wireless Systems
Overview of the Radio Spectrum



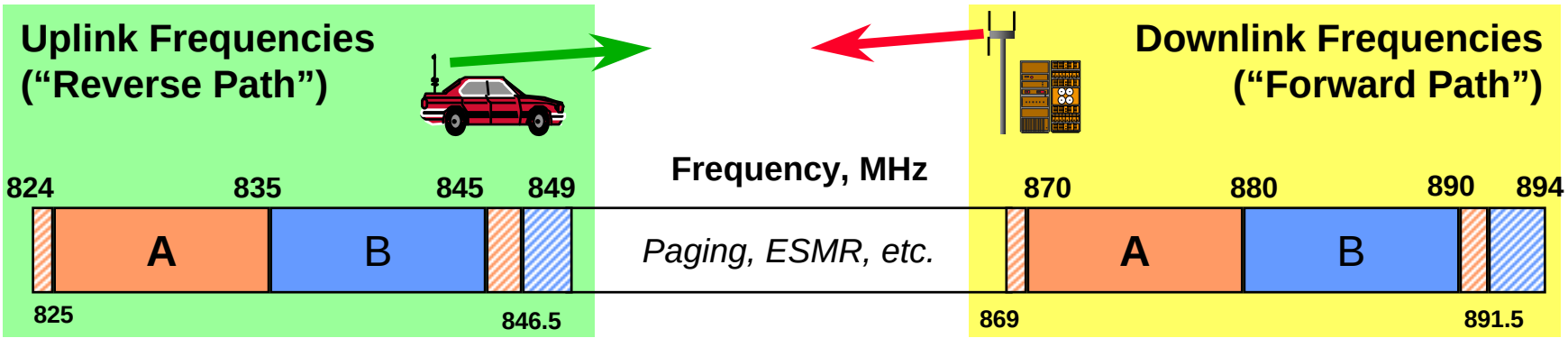
Development of North American Cellular

- 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

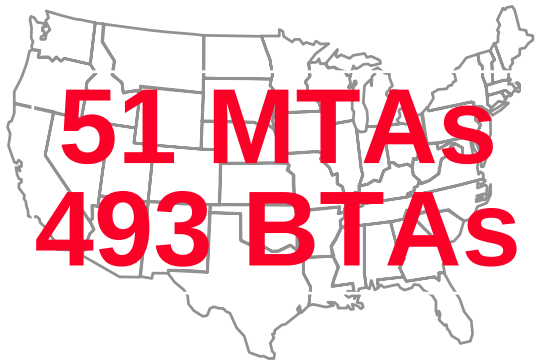
Frequencies used by "A" Cellular Operator
Initial ownership by Non-Wireline companies

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 awareded to existing telephone companies only
  - subsequent sales are unrestricted after system in actual operation

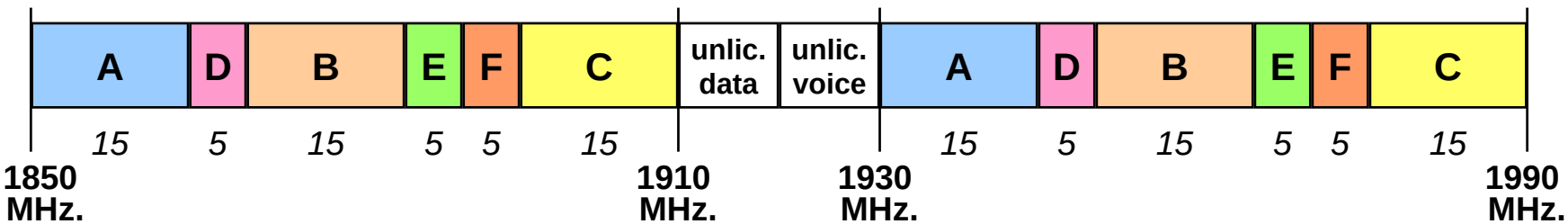
Development of North America PCS

- 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

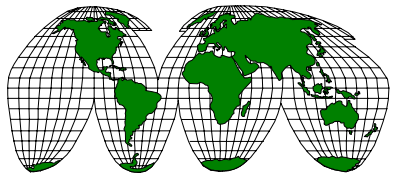


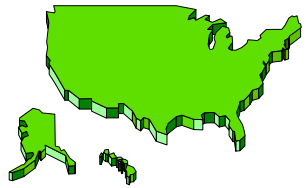
- PCS Licensing and Auction Details
  - A & B spectrum blocks licensed in 51 **MTAs** (Major Trading Areas)
    - Revenue from auction: $7.2 billion (1995)
  - C, D, E, F blocks were licensed in 493 **BTAs** (Basic Trading Areas)
    - C-block auction revenue: $10.2 B, D-E-F block auction: $2+ B (1996)
  - Auction winners are free to choose any desired technology

PCS SPECTRUM ALLOCATIONS IN NORTH AMERICA



Global and US Wireless Snapshot 4Q 2003

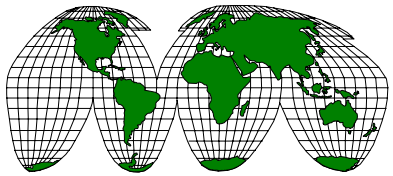


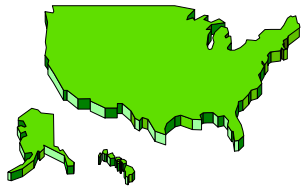


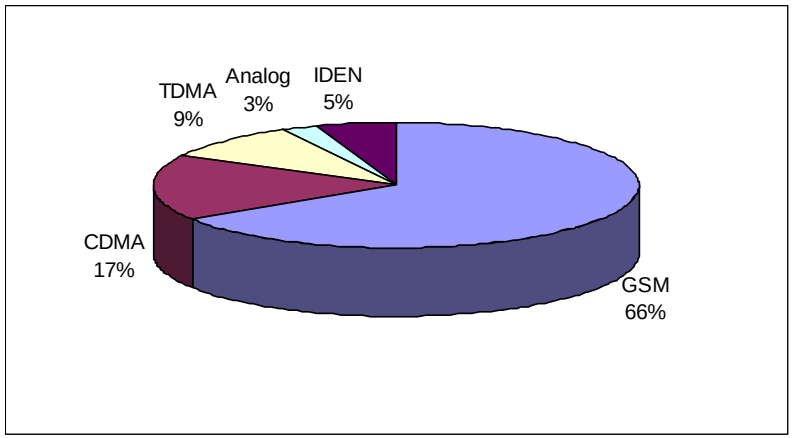
	Worldwide		USA	
Total Wireless Users	**1,320,000,000**	***100%***	**141,000,000**	***100%***
GSM users	**870,000,000**	***65.9%***	**33,732,506**	***23.9%***
CDMA users	**224,000,000**	***17.0%***	**64,503,287**	***45.7%***
TDMA users	**124,000,000**	***9.4%***	**26,375,232**	***18.6%***
IDEN users	**68,000,000**	***5.2%***	**11,978,382**	***8.5%***
Analog users	**34,000,000**	***2.6%***	**4,510,594**	***3.2%***

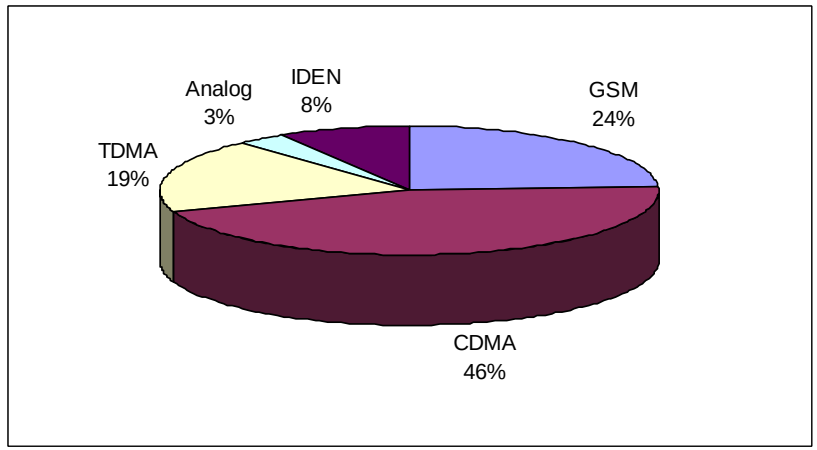
- Total Worldwide Wireless customers surpassed total worldwide landline customers at year-end 2002, with 1,00,080,000 of each.
- 2/3 of worldwide wireless customers use the GSM technology
- CDMA is second-most-prevalent with 17.0%
- In the US, CDMA is the most prevalent technology at 45.7%
- Both CDMA and GSM are growing in the US
  - most IS-136 TDMA systems are converting to GSM + GPRS + EDGE

Global and US Wireless Users by Technology









- GSM is by far the dominant global technology
- CDMA is dominant in its country of origin, the USA
- The IS-136 TDMA community is rapidly implementing GSM
  - primary motivation is to provide GPRS and/or EDGE fast data

US Wireless Operators: Technologies and Subscribers

141,000,000	Totals:	64,503,287	33,732,506	26,275,232	11,978,382	4,510,594
Company	Subscribers	CDMA	GSM	TDMA	IDEN	Analog
Verizon	33,166,130	29,849,517				3,316,613
Cingular	22,348,869		11,174,435	11,174,435		
AT&T Wireless	21,328,373		10,664,187	10,664,187		
Sprint PCS	15,103,346	15,103,346				
Nextel	10,817,261				10,817,261	
T-Mobile	10,102,914		10,102,914			
Alltel	7,755,772	6,980,195				775,577
US Cellular	4,184,035	2,928,824		836,807		418,403
Leap Wireless	1,530,744	1,530,744				
Western Wireless	1,224,596		1,224,596			
Dobson	1,122,546	1,122,546				
Quest	1,020,496	1,020,496				
Nextel Partners	895,792				895,792	
Triton PCS	847,012		423,506	423,506		
Rural Cellular Corp.	736,801			736,801		
Alamosa Holdings	634,749	634,749				
Airgate PCS	601,518	601,518				
US Unwired	552,374	552,374				
Centennial	540,863			540,863		
Midwest Wireless	288,313	288,313				
SourhernLINC	265,329				265,329	
Ntelos	256,166	256,166				
Horizon PCS	246,858	246,858				
Ubiquitel	239,408	239,408				
MetroPCS	1,694,024	1,694,024				
Cellular South	561,273	280,636		280,636		
Commnet PCS	357,174			357,174		
NewComm	306,149	306,149				
West Coast PCs	295,944	295,944				
Meriwether Communications	275,534			275,534		
Touch America	224,509	224,509				
Airadigm Communications	163,279			163,279		
Cellcomn	163,279	163,279				
Conestoga Wireless	142,869		142,869			
Lewis and Clark	132,665			132,665		
Public Service Cellular	112,255			112,255		
Entertainment Unlimited	112,255			112,255		
NPI Wireless	112,255			112,255		
Poplar PCS	102,050	102,050				
CorrWireless	102,050			102,050		
Iowa Wireless	102,050			102,050		
NTCH	81,640	81,640				
Edge Wireless	75,006			75,006		
Skagit Wireless	73,476			73,476		