Course 311

General Introduction to GSM, GPRS/EDGE, and UMTS/WCDMA/HSPA

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  - The network: parallel circuit-switched voice and packet data branches
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Introduction

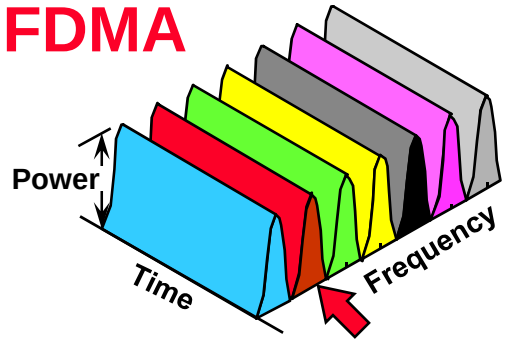
The Role of Standards Organizations

- Our modern wireless technologies have been created by many companies and wireless groups working together under the leadership of standards organizations
- In the United States, we have a history of individual companies developing products which became so widely used that they are regarded as “de facto” standards in an industry
  - For example, Motorola, E. F. Johnson, and others developed individual standards for two-way “trunked radio” used by individual businesses and law enforcement
  - De facto standards usually involve intellectual property and patents of their developers and hefty licensing fees are charged for other companies to use the same techniques
- The European way to manage standards is to use standards organizations to “sponsor” specific standards, and to persuade developing companies to allow use of their proprietary techniques at reasonable prices to allow competition and wide adoption

Wireless Families and Standards Organizations

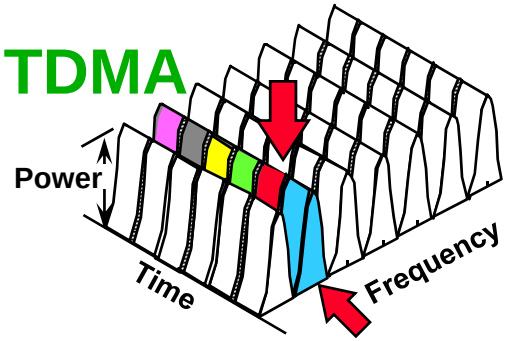
- The ITU (International Telecommunications Union) is the “mother” umbrella organization for telecommunications standards around the world
  - Standardizes radio spectrum assignments around the world, providing a forum for negotiation between industries and governments
- The ETSI (European Telecommunications Standards Institute) is the official sponsor of GSM, GPRS, EDGE, UMTS, and HSPA, and a competitor to CDMA, EVDO, and WiMAX
- ANSI (American National Standards Association) issues voluntary consensus standards for a wide range of products, from photographic film speeds to manufacturing processes, alternative fuels, and even WiMAX, aiming for American products to be usable around the world
- The TIA (Telecommunications Industry Association) is a technical forum producing standards for North American telecommunications
  - It issues wireline and wireless telephone standards, including AMPS, CDMA, EVDO, WiMAX,
- The EIA (Electronics Industry Association) represents electronics manufacturers primarily in North America

Multiple Access Methods



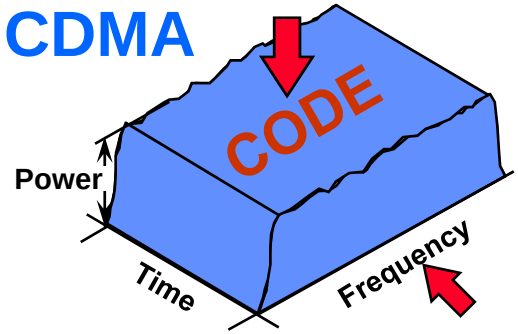
FDMA: AMPS & NAMPS

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



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

•Each user uses a signal on a particular frequency at the same time as many other users, but it can be separated out when receiving because it contains a special code of its own

GSM: The “Mother” of 2G Wireless Technologies

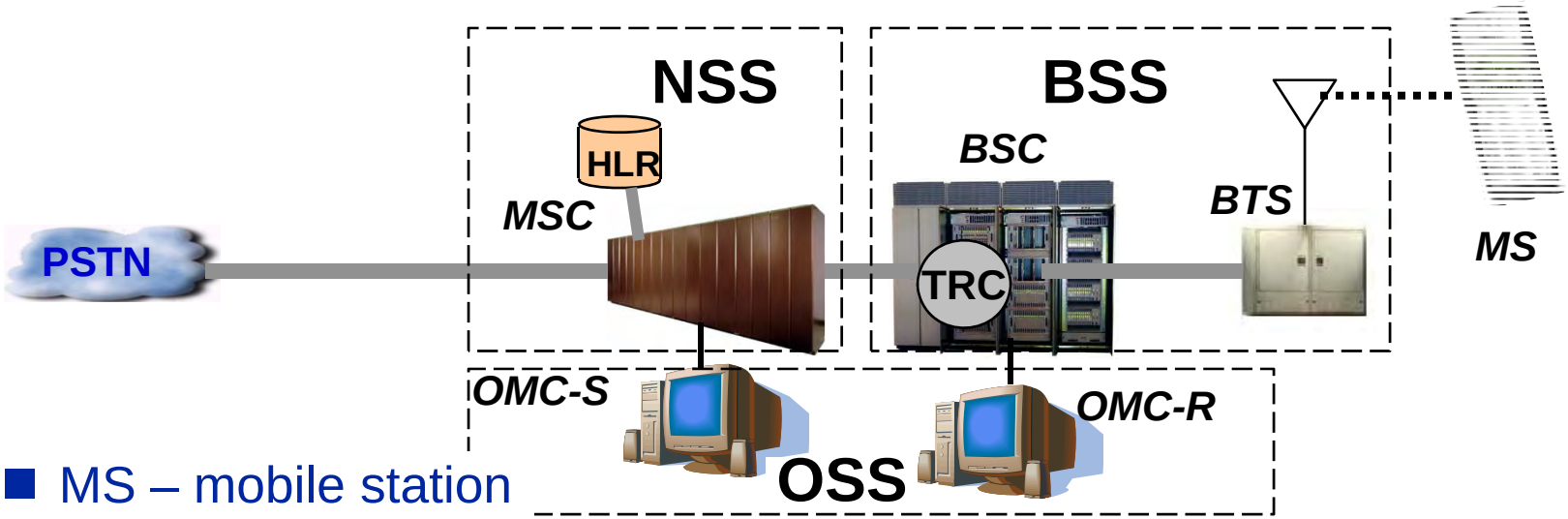
The Birth of GSM

- In 1983, The US had just implemented its analog cellular systems, using the AMPS technology – Advanced Mobile Phone Service
  - Developed by AT&T Bell Labs, with Motorola contributions
- Europe preferred to leapfrog to a digital technology, standardized so it could be implemented internationally on a wide scale
- The ETSI Group Special Mobile (GSM) developed the standard, which bears its initials, in 1982
  - Today marketed as "**G**lobal **S**ystem for **M**obile communication"
- GSM was field-tested in 1986, a "memorandum of understanding" signed in 1988, and commercially launched in 1991
  - By 1995 coverage of most of Europe was complete
- Today there are more than 5 billion GSM users in 212 countries worldwide, about 80% of the global mobile market.

Standards for just Radio, or the whole Network?

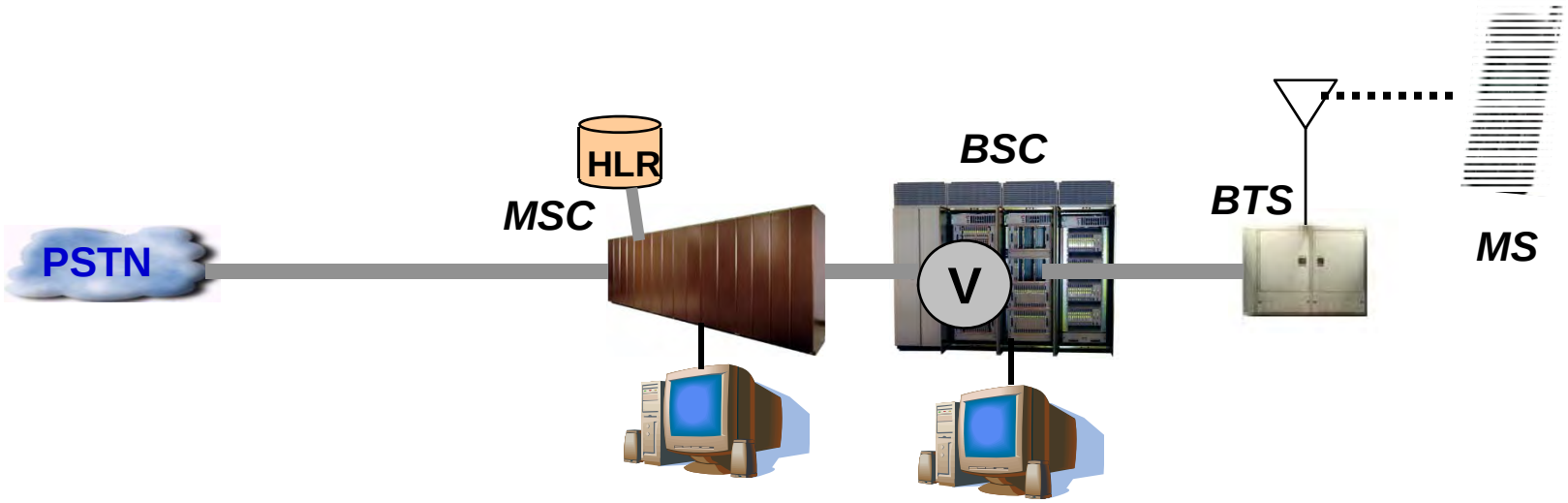
- The American cellular technologies AMPS (TIA-EIA 553), US TDMA (IS-136) and CDMA (IS-95) all began as radio standards, specifying the radio signal details without much reference to the elements of an overall network
  - A separate standard, IS-41, had to define how networks would handle intersystem handoff and roaming call delivery
- The ETSI standards for GSM, GPRS and EDGE in contrast provide extensive specifications not only for the radio signal but also for the major functional blocks of the network and the network functioning as a whole
  - This allows much better interworking between networks of different operators, and even some limited opportunities to blend equipment from different manufacturers into the same network, for cost savings and easier expansion

Basic GSM Network – Voice Only



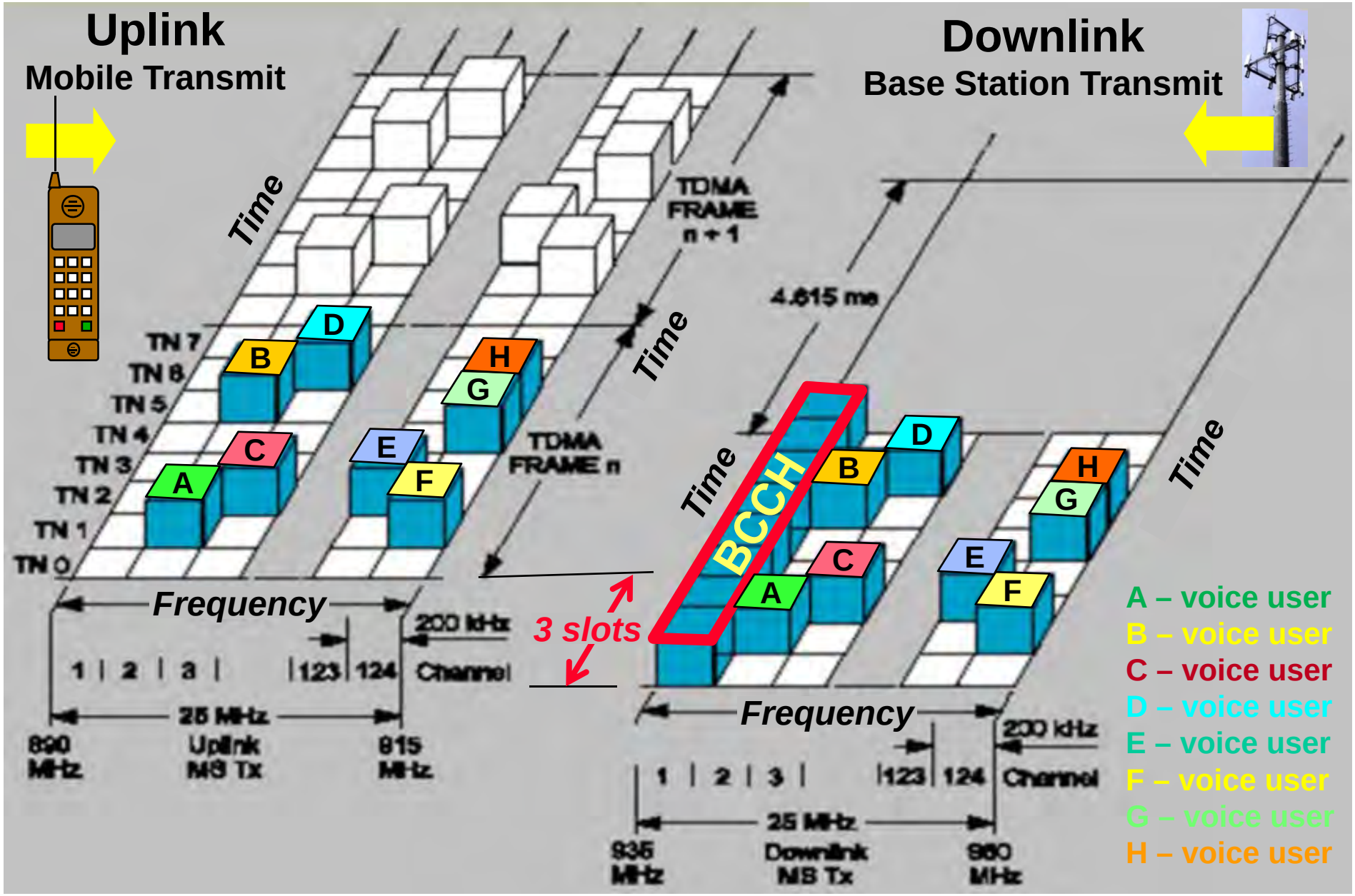
- MS – mobile station
- BSS – base station subsystem
  - BTS – base transceiver station, BSC – base station controller
- NSS – network subsystem
  - MSC – Mobile Switching Center
- PSTN – public switched telephone network
- OSS – Operations Subsystem
  - OMC-R – Operation and Maintenance Center – Radio
  - OMC-S – Operation and Maintenance Center – System

Compare with
A CDMA Network – Voice Only



- The elements in a CDMA voice-only network map almost exactly to their counterparts in a GSM voice-only network.
- Americans are just a little less formal about the overall architecture of things, allowing each network manufacturer to implement the connections between elements and the overall network organization as they wish

GSM On Radio: Time Division Multiple Access:
GSM Uplink and Downlink Frequencies and Timing

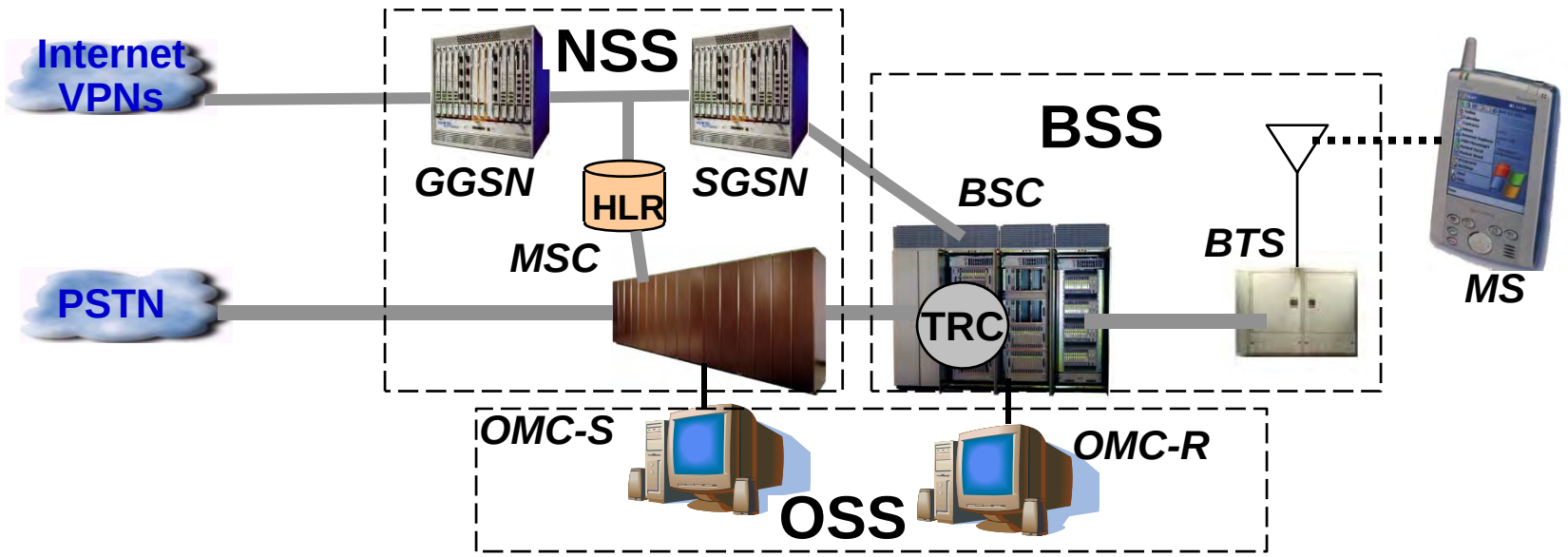


Data over the 2G GSM Signal?
GPRS and EDGE

GSM "Add-ons": GPRS and EDGE

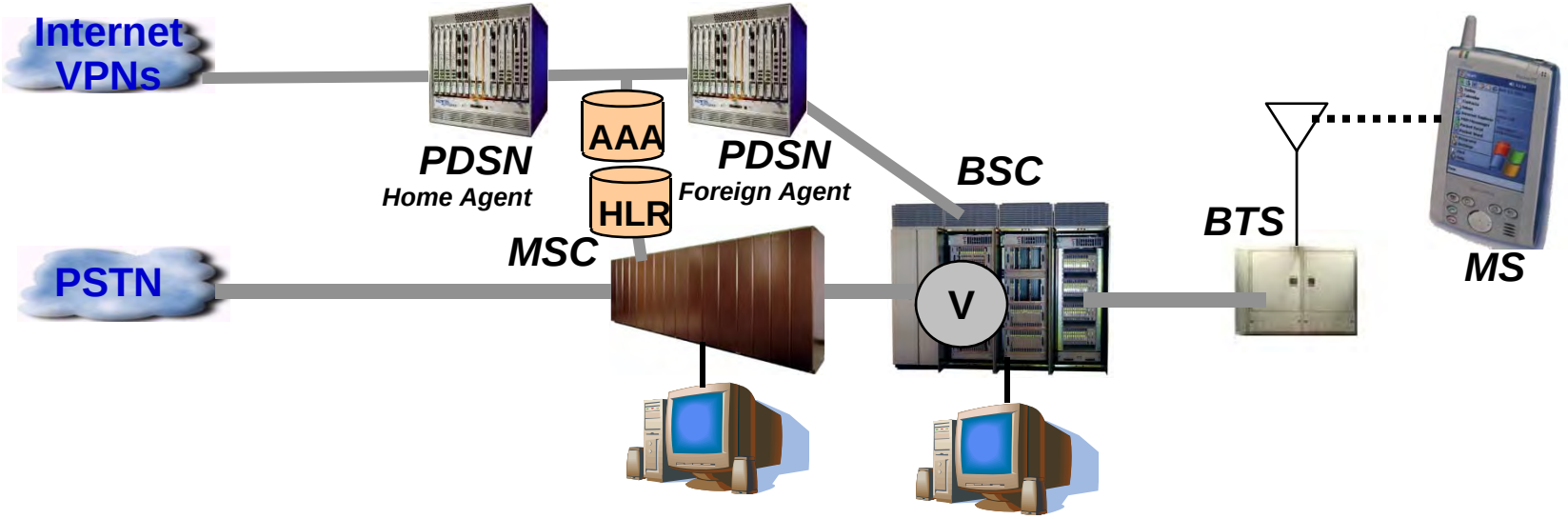
- GSM was designed for voice calls only, but interest in mobile data grew and eventually a data service, HSCSD "High Speed Circuit Switched Data" was implemented at 32 kb/s using the GSM signal.
- There was demand for higher speeds than HSCSD, so the General Packet Radio Service (GPRS) was developed in 1998
  - GPRS uses timeslots in the GSM signal for packet data and delivers typical data speeds of around 40 kb/s
- There was demand for even higher speeds than GPRS, so Enhanced Data rates for GSM Evolution (EDGE) came in 1999
  - EDGE uses timeslots in the GSM signal like GPRS, with more advanced modulation (8PSK) for typical speeds up to 200 kb/s
- Today virtually every GSM phone or device sold, and all worldwide GSM networks, have both GPRS and EDGE capability
  - GPRS and EDGE users are normally billed for volume of data, and prices are substantially higher than for later technologies
- A GSM base stations is called a BTS (Base Transceiver Station)

A GSM/GPRS Network – Voice *and* Data



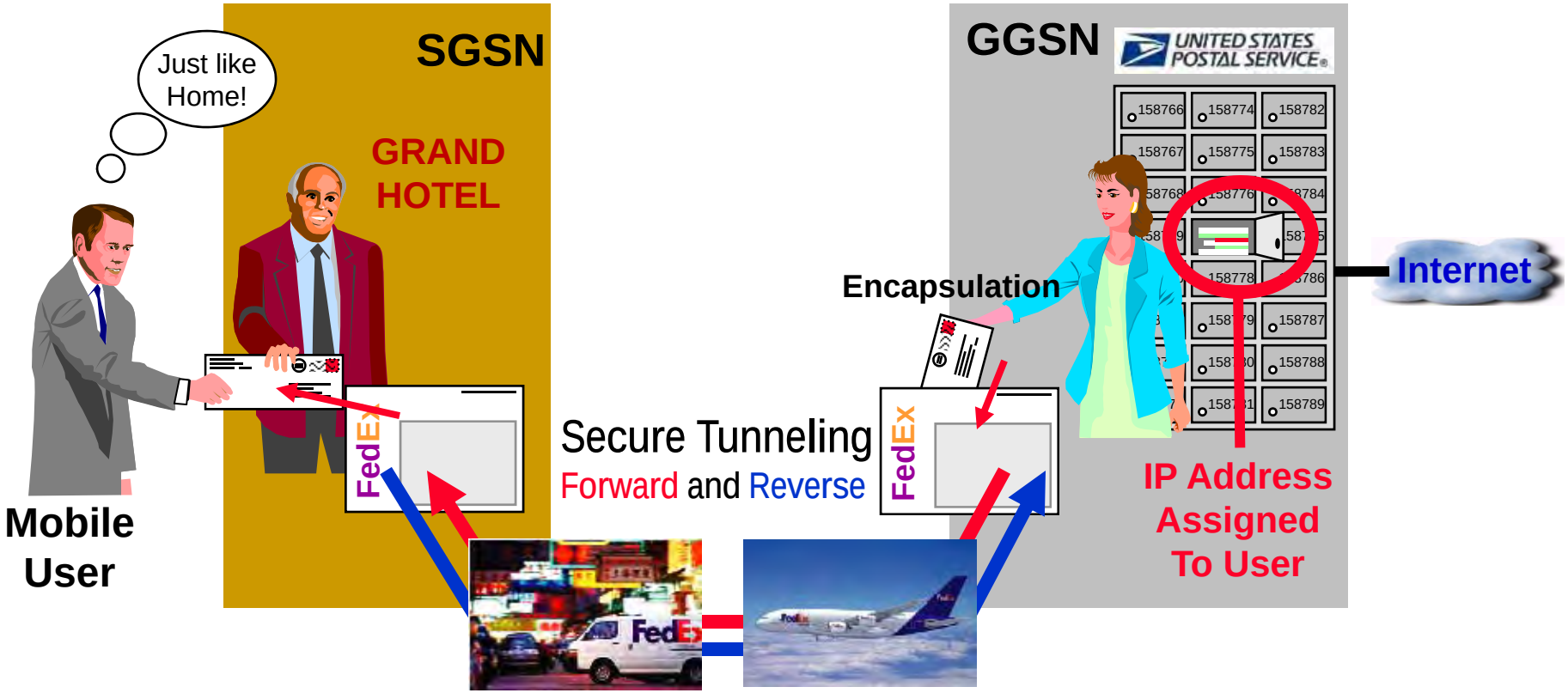
- Adding GPRS packet services to a GSM network requires two new network elements, the GGSN and the SGSN
- GGSN Gateway GPRS Support Node
  - Hosts IP addresses, routes data packets into and out of the radio network; acts as a router for packets within the network
- SGSN Serving GPRS Support Node
  - Maintains packet delivery connection with mobiles in its area
- Data is "tunneled" from the GGSN to the SGSN using GTP, GPRS Tunneling Protocol, carrying packets between mobile and GGSN
- PCU Packet Controller Unit manages RF timeslots for packets

Compare with
A CDMA/1xRTT Network – Voice *and* Data



- The network elements of GSM/GPRS/EDGE networks have direct counterparts in CDMA/1xRTT networks
- The GGSN performs the same function as a 1xRTT PDSN Home Agent
  - It is the "anchor" point for a range of internet IP addresses
- The SGSN performs the same function as a 1xRTT PDSN Foreign Agent
  - It routes packets to and from the GGSN to actual users no matter where they are in the network
- The HLR function in CDMA networks applies only to voice calls. A separate function "AAA" serves as the data "HLR".
- The MSC and BSC administrative functions are handled by separate terminals, like the OMC-S and OMC-R, but with proprietary mfr's. names

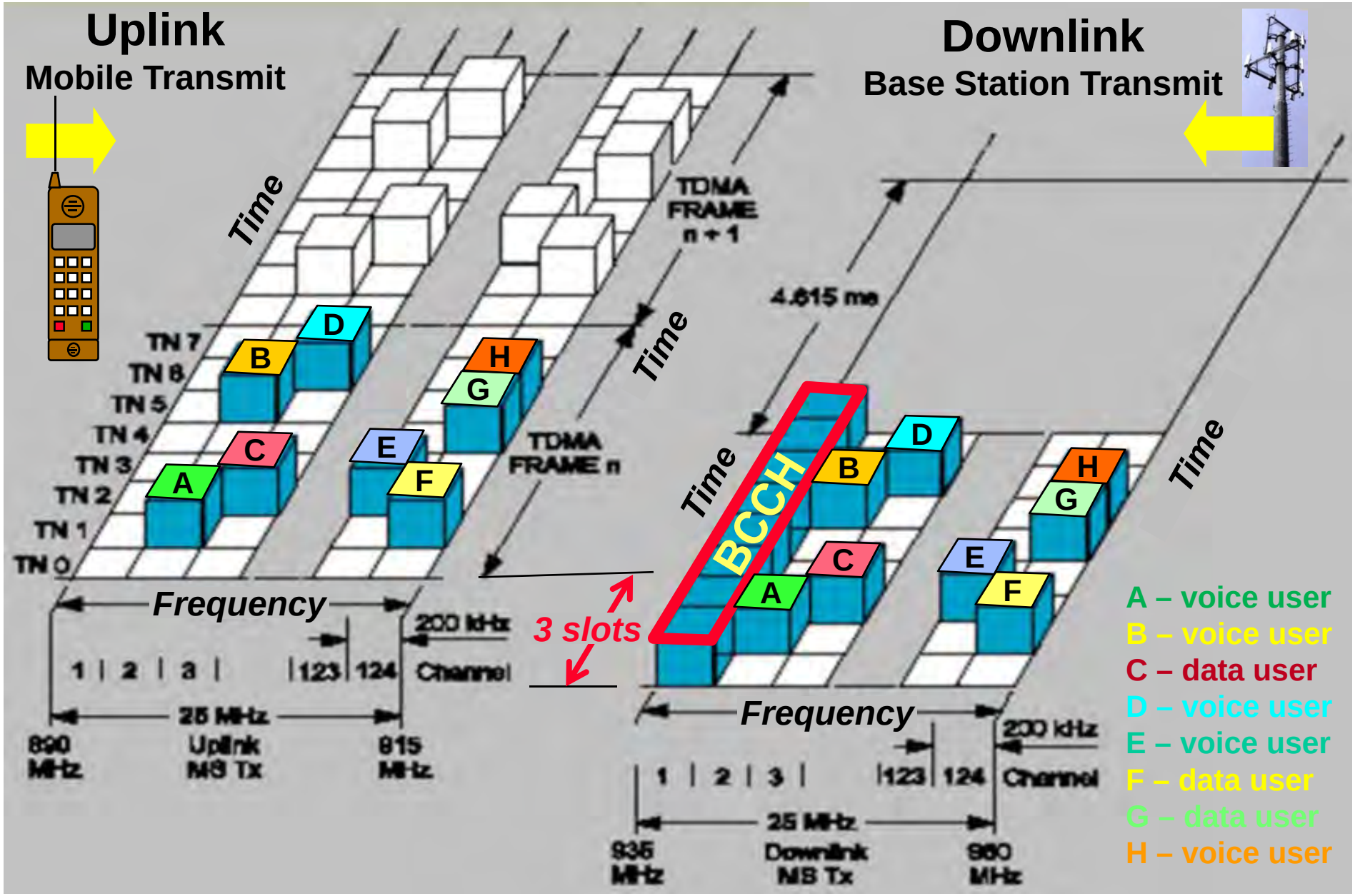
How does a User get their packets anywhere? Through Tunnels between the SGSN and GGSN



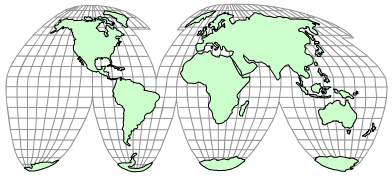
The GPRS-EDGE (and even UMTS/HSPA) packet network relies on secure tunneling to forward packets in both directions between a User, the SGSN, and the GGSN which actually "owns" the internet IP address assigned to the User at that moment.

GSM and GPRS Radio Operations Together

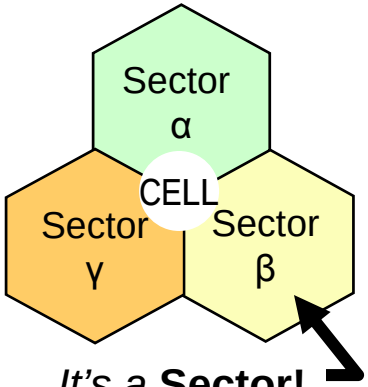
A Mix of Voice and Data Users on Different Timeslots



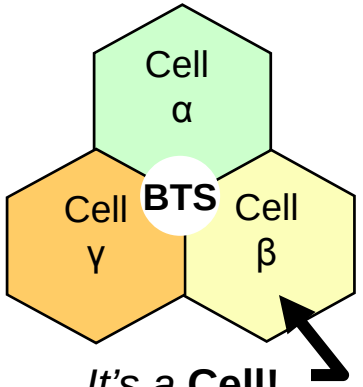
GSM/GPRS Terminology: Cells and Sectors



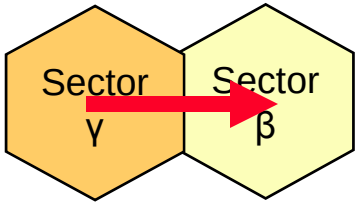
- Some terms have different meanings when used in GSM or North American practice!



It's a **Sector!**

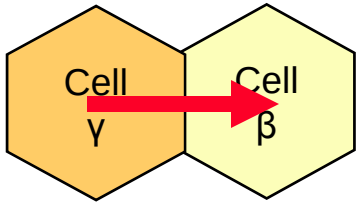


It's a **Cell!**



That was a **Handoff!**

The frequencies used by each sector are its **channel set**.



That was a **Handover!**

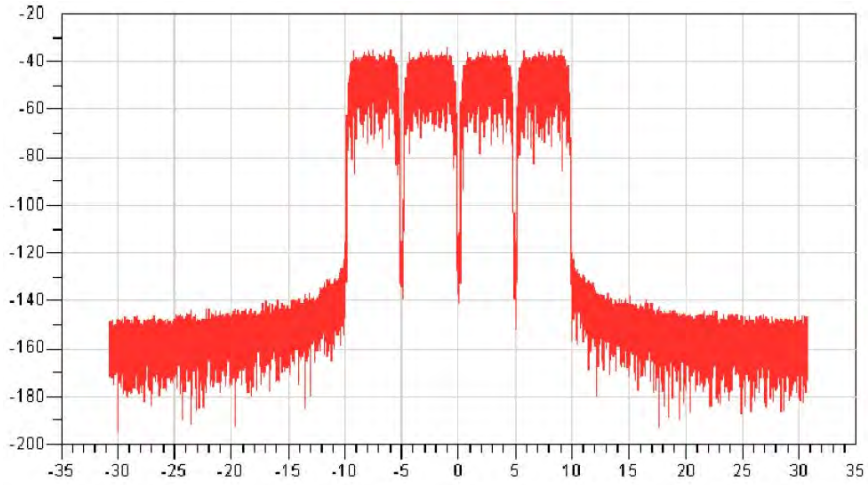
The frequencies used by each cell are its **allocation**.

True 3G:
UMTS - WCDMA

Higher Speeds: UMTS / WCDMA

- Even the best speeds of EDGE are still far below the data speeds of DSL and Cable Modems for users in homes and businesses
- The ETSI combined the GSM, GPRS, and EDGE standards and added a new wideband technology for even higher data rates
- The new overall family is called UMTS (Universal Mobile Telecommunications Services) and that is the name normally used for the new technology, based on wideband CDMA (WCDMA)
  - Different and not directly compatible with US CDMA
  - The UMTS/WCDMA signal can carry up to roughly 200 voice calls as well as data bursts up to as much as 2 Mb/s overall
  - One UMTS signal occupies about 3.84 MHz. of radio spectrum, and can fit within a licensed spectrum block 5 MHz. wide
    - This is about 3-times wider than a US CDMA signal
- A UMTS base station is called a “Node B”

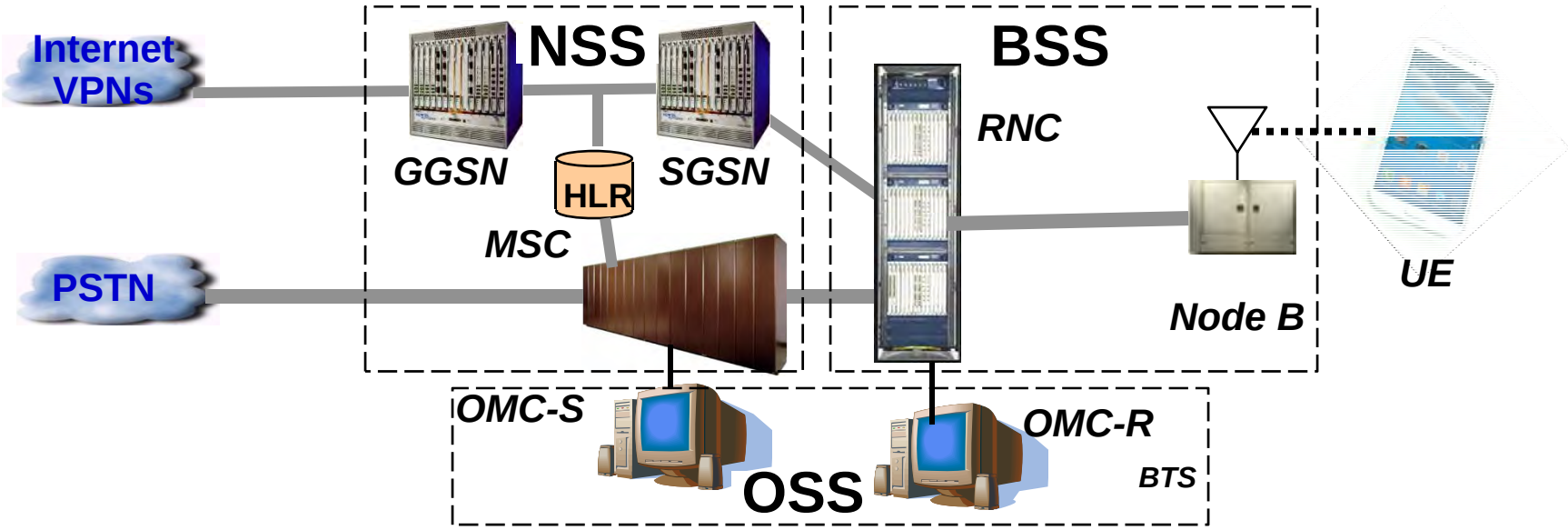
The UMTS / WCDMA Radio Signal



At left, four UMTS/WCDMA carriers stand side by side in 20 MHz. of spectrum. Each of the carriers can handle in excess of 200 voice calls as well as numerous data connections with peak rates up to 1 Mb/s each. As we'll see in the next section, one or more of the carriers can also handle HSPA fast data too.

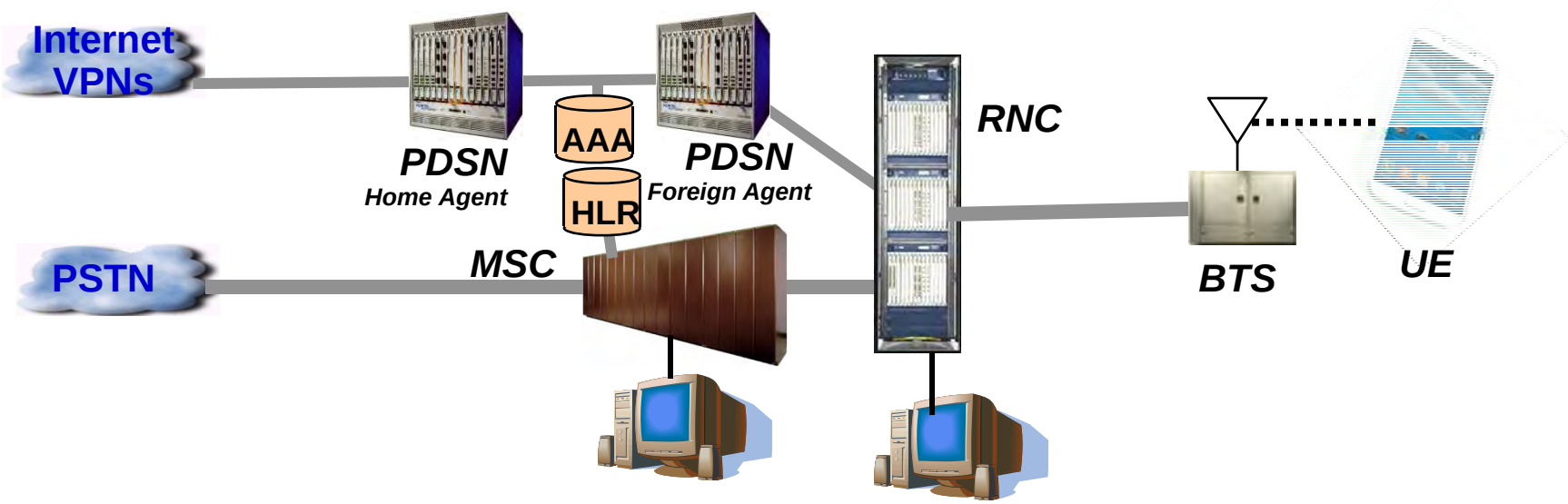
- The UMTS signal uses wideband CDMA
  - RF bandwidth is 3.84 MHz., 3x wider than US CDMA signals
  - UMTS uses up to 256 codes, same as US CDMA Walsh codes but called "OVSF" **O**rthogonal **V**ariable **S**preading **F**actor
  - UMTS establishes timeslots for use of the OVSF codes, creating "TDMA in a WCDMA shell" for operational flexibility
  - Up to two 1 Mb/s data channels can exist at any instant
  - Instead of a PN "short code" with timing offsets to distinguish sectors, UMTS uses 512 different Gold Codes as carriers

A UMTS Network



- The core voice and packet network in UMTS is the same as in GSM/GPRS, but the BSS Base Station Subsystem is changed a lot
- Radio Resource Control for packet and voice and the packet control function uses a new element, the RNC **R**adio **N**etwork **C**ontroller
- Each base station is now called a “Node B”
- A customer mobile is now called a UE, User Equipment
- The required SIM card is special, including UMTS features

Compare with An EV-DO Network



- The network elements of UMTS networks have direct counterparts in CDMA/EV-DO networks
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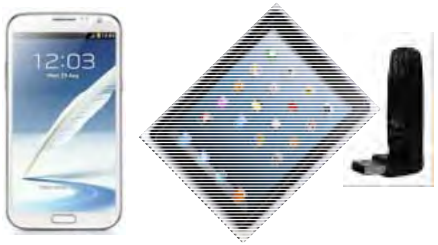
Almost 4G: HSPA, HSPA+

Even Higher Speeds – HSPA and HSPA+

- As UMTS was born, Qualcomm and American operators had applied the newest principles to its CDMA technology, producing a hybrid variation called EVDO (Evolved, Data Optimized).
  - Adding higher order modulation to the basic CDMA signal, EVDO offered data speeds of up to 3.1 Mb/s downlink, 1.8 Mb/s up on a single CDMA-like signal just 1.2 MHz. wide
- The ETSI community wasted no time doing the same to its UMTS /WCDMA signal, achieving speeds of up to 7 Mb/s downlink, 3.5 Mb/s uplink on a single UMTS-like signal just 3.8 MHz. wide
  - This signal was called HSPA, High Speed Packet Access
  - Downlink and uplink versions were call HSDPA and HSUPA
- If multiple HSPA signals are harnessed together for even greater speed, this is called HSPA+
  - The most advanced HSPA+ multicarrier arrangements offer up to 44 Mb/s downlink, 22 Mb/s uplink
- AT&T and T-Mobile have advertised HSPA+ as a “4G technology”

Calling Things by their Official Names

4G LTE	**UE** User Equipment		**eNb, eNodeB** Enhanced Node B
3G UMTS HSPA	**UE** User Equipment		**Node B**
2G GSM GPRS/EDGE	**Mobile** Handset, Terminal		**Cell Site, BTS** Base Station
1G Analog	**Mobile** Handset, Terminal		**Cell Site,** Base Station
Pre-Cellular	**Mobile**		**Base Station**

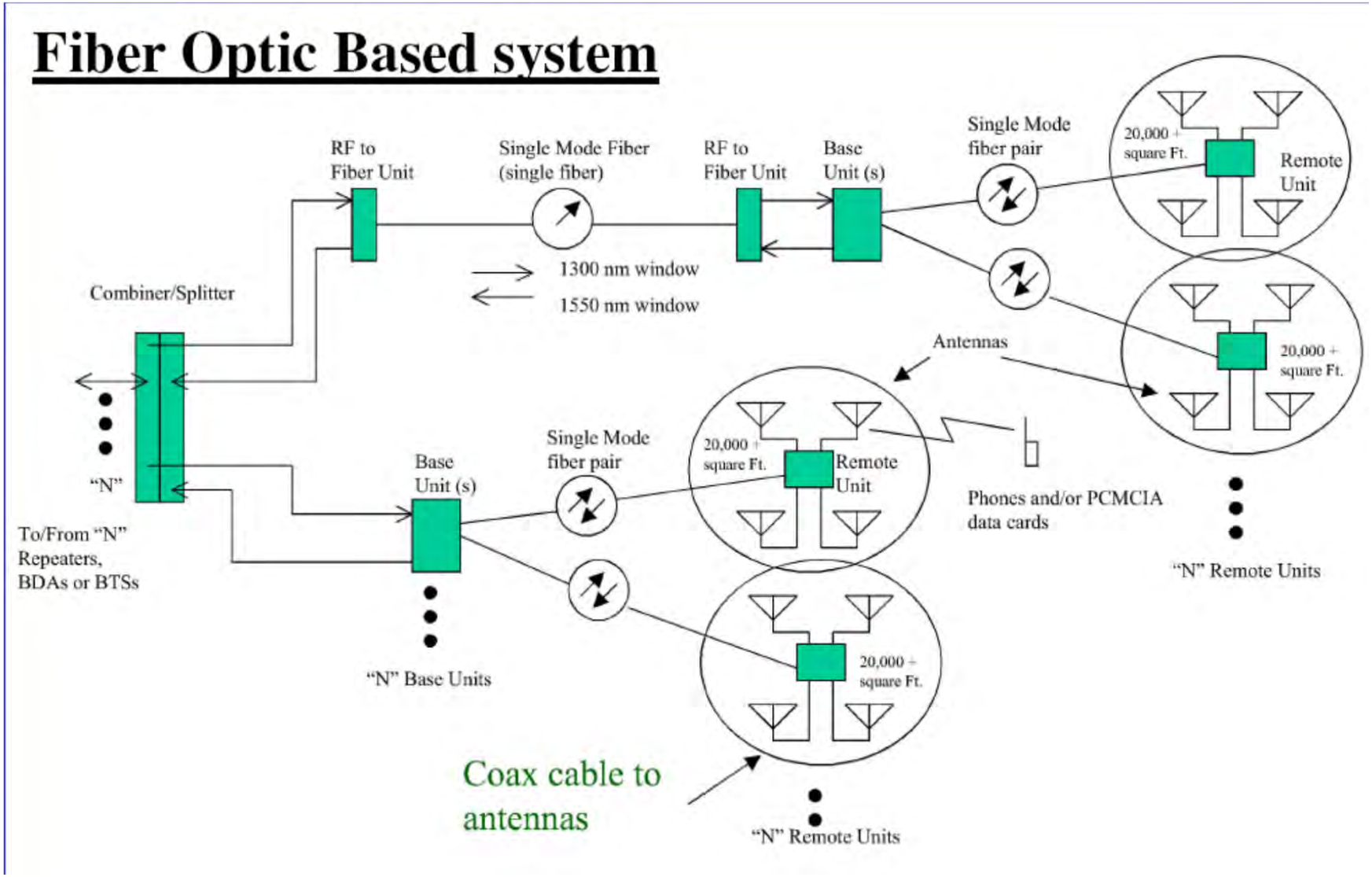
Traditional Network Architecture

- Traditional wireless systems were composed mainly of macrocells
  - The network structure was homogeneous, composed of many similar cells in a uniform fabric
  - Cells covered large areas of a city or rural area
  - Cells used relatively large transmit power and antenna heights
  - Cells used conventional backhaul technologies
  - Network growth was managed at a high level, with substantial cost and effort levels involved in adding new or expanded cells
- Construction and Expansion of classical homogeneous networks faces increasing obstacles
  - Addition of new cells is expensive and slow
  - major regulatory obstacles and public opposition are often encountered
  - Traffic bottlenecks are difficult to relieve

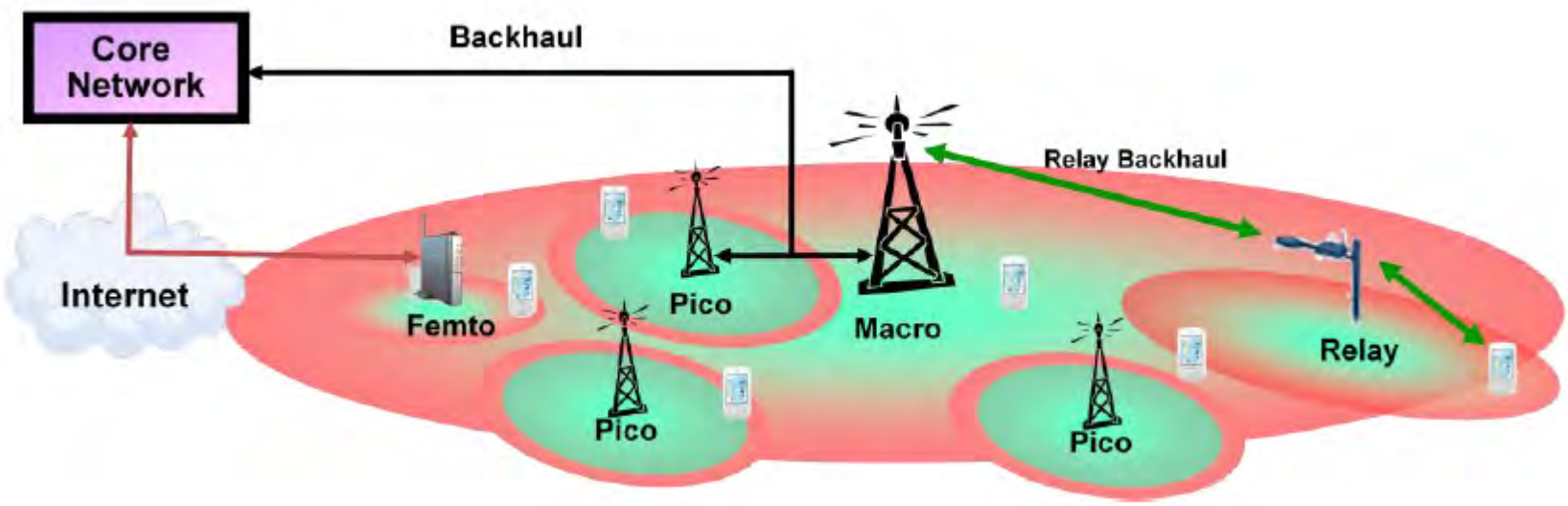
Additional Wireless Developments

- Along with improvements in signal capacity and data speeds, wireless operators are also using advanced techniques to improve the scope and reach of wireless delivery to new places and users
- DAS **D**istributed **A**ntenna **S**ystems can extend coverage in malls, sports and entertainment venues, tunnels, and any place where large numbers of users gather but have poor or no coverage
  - A private DAS amplifies the signal of just one operator or group
  - A neutral-host DAS amplifies the signal of many wireless operators, who share the cost.
- Micro-, Pico- and Femto-cells and Home eNodeBs can extend coverage into homes, businesses and small venues
  - Normally sold in operator's retail stores, their prices are subsidized to be more attractive to customers
  - They require customer-provided DSL or cable broadband access to connect with the wireless operators' core networks
- A network with a diverse mix of macro-BTS and micro/pico/ femtocells is called a Heterogeneous Network ('HetNet')

Typical Large-Venue Neutral-Host DAS



What's a Heterogeneous Network (HetNet)?



- A heterogeneous network is a non-uniform, seemingly disjointed combination of macro and micro/pico/femtocells, delivering RF where it is needed most in both outdoor and indoor environments
  - Macrocells continue to deliver widespread public coverage
  - Distributed antenna systems ("DAS") serve large public venues where traditional cells aren't effective
  - Non-traditional small cells are used to deliver coverage to individual homes, businesses and problem areas
  - Non-traditional backhaul is used (in-band relay, home broadband, etc)
- Solutions to traffic or coverage problems can be achieved much more quickly using non-traditional methods

Heterogeneous Network Details and Critical Considerations

- Multi-Band Deployment
  - Overlay-Underlay, or Segmented?
    - – non-traditional spectrum strategies
  - Transition triggers and methods
  - Micro-Pico-Femtocell on Customer Premises
  - Backhaul availability and economics
  - Pricing – operator vs. customer contribution, business plan
  - Transition triggers and methods
  - Special factors: S1 vs X2? Doppler and other exotic triggers?
  - WiFi access by UE
  - WiFi networks: operator provided, business-hosted, user premises?

The Final (for now) Frontier: LTE

Where do we go from here?

- The whole telecommunications world is converging on the next ETSI standard, LTE Long Term Evolution. LTE offers
  - Higher data speeds and lower packet latency than any previous radio technology
  - A streamlined packet core network
  - A non-proprietary method for providing mobility and roaming
  - A better user experience through Quality of Service (QOS)
  - Lower costs through widespread use and economies of scale
  - A vehicle for handling voice calls with much greater spectral efficiency, offloading most voice traffic from 2G/3G networks within five years
- LTE is described in companion course 511
- What comes after LTE?
  - More advanced signal, smaller cells, higher speeds
  - Call it “5G” for now and look for it in 10 years!