Content for protocols - Multiple Access Division Techniques

- Allow access of the same medium without collision
- Accomplished through making signals orthogonal along one or more coordinates
- Orthogonality may be exploited
  - Frequency - FDMA/OFDMA
  - Time - TDMA
  - Space - SDMA
  - Code - CDMA

It is not uncommon to have multiple access techniques combined in a single air interface.

For example, GSN implements FDMA/SDMA access with frequency hopping.

**Frequency division multiple access (FDMA)**

- Handout - Cellular frequency allocation chart (posted on the Web as well)

- FDMA used in systems deploying paired frequency allocation and FDD
- The allocated spectrum is segmented into smaller frequency segments called channels

Channel = pair of frequencies \( f_{UL}, f_{DL} \) that are used in full duplex communication.

One frequency is used on UL and the other one is used on DL.

The number of channels that are available depends on a given technology and how available spectrum for a given system.
Case study 1: Consider deployment of GSM within US - PCS A Block

PCS UL - 1850 - 1910 MHz
   DL - 1930 - 1990 MHz

A block: 15 MHz
   UL 1850 - 1865 MHz
   DL 1930 - 1945 MHz

GSM channel: 200 KHz (0.2 MHz)

# Channels = \frac{15 \text{ MHz} - 2.0 \text{ MHz}}{0.2 \text{ MHz}} = 74 \text{ Channels}

Channels are: 512-585 MHz

Channel/Frequency Formula \quad f_{DL} = 1930 + (\text{Channel number - 511}) \times 0.2 \quad [MHz]

For example: Channel 534 has a frequency pair given as

\[ f_{DL} = 1930 + (534 - 511) \times 0.2 = 1934.6 \text{ MHz} \]
\[ f_{UL} = f_{DL} - \text{Duplex Space} = 1934.6 \text{ MHz} - 80 \text{ MHz} = 1854.6 \text{ MHz} \]

In GSM, channels are referred to as the ARFCN (Absolute Radio Frequency Channel Number)

Therefore \quad ARFCN(534) = (1854.6, 1934.6) - Frequency pair.

Consider A-block GSM deployment in reuse N=4/12

\[ 4/12 \Rightarrow \text{Cluster size N=4 sites, each site is three sectors} \]
\# Channels per site = \frac{Total number of channels}{N} = \frac{74}{4} = 18.5

(some sites will get 18 and some will get 19)

\# Channels per sector = \frac{Total number of channels}{k} = 6.17

(some sites will get 6 and some will get 7)

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(1854.6, 1934.6) MHz

\{ A (61, 55, 59), B (52, 56, 510), C (53, 57, 511), D (54, 58, 512) \}

\begin{center}
\textbf{Regular 4/12 reuse frequency plan}
\end{center}

\textbf{Note: Deployment may not follow regular reuse. If that is the case we talk about "MD-TOC" plan.}
Time Division Multiple Access (TDMA)

* In cellular systems TDMA is implemented on a hop of FDMA.
* TDMA - one channel is used by multiple users. The channel switching is conducted in time domain. That is, each user is assigned with the channel for a duration of one time slot. Consider Figure below:

\[
\begin{align*}
U_1 & \quad R_1 & \quad U_1 \text{Rx} \\
U_2 & \quad R_2 & \quad R_u = N \times R_u & \quad R_2 & \quad U_2 \text{Rx} \\
U_3 & \quad R_3 & \quad (radio \ interface) & \quad R_u & \quad U_3 \text{Rx}
\end{align*}
\]

* Time is divided into N equal time slots.
* For the duration of a time slot, the channel is assigned to \((TX, RX)\) pair.
* The number of users sharing the same channel is technology-dependent.
* In GSM, there are 8 users/channel for or 16 users/channel in HLR.
* Note that the role on the radio channel is \(N \times \) rate of individual users.

**Example** TDMA in GSM (FR)

* Eight users per channel.
* Transmission is "accumulate and burst" - the user accumulates data until the channel is allocated. When the channel is allocated, the user sends bursts of data over the channel.
* The rate on the channel is 270.833 kbps on the radio interface.
* Each user gets \(270.833/8 = 33.85\) kbps.
* Voice uses: 13 kbps (little is coding overhead)
* Data uses: 9.6 kbps (there is coding overhead).
Near-far problem in TDMA schemes.

* TDMA requires strict synchronisation between users on one UL segment.

Consider the situation depicted in the figure:

- Time slots occupied by one user
- The remaining time slots are available to other users in the cell

\[ d_2 \gg d_1 \]
\[ \tau_1 = \frac{d_1}{c} \]
\[ \tau_2 = \frac{d_2}{c} \quad \text{since } d_2 \gg d_1 \Rightarrow \tau_2 \gg \tau_1. \]
If nothing is done, the two bursts will collide.

To avoid collisions, the users are directed to advance their transmissions so that their bursts fill in appropriate time slots.

**Example:** Consider deployment of GSM in a block of 12 PCS. If the reuse scheme selected for deployment is 4/12. Determine the maximum number of simultaneous users that may be served by a cell.

\[ \text{# channels} = \frac{15 - 0.1 \times 2}{0.2} = 74 \text{ channels} \]
\[ \text{# channels/sector} = \frac{74}{12} = 6.17 \text{ channels/sector} \]
\[ \text{# users/sector} = 6.17 \times 8 = 49.36 \text{ users/sector} \approx 49 \text{ users at the maximum} \]

TDMA access is very efficient for voice.

Voice is narrowband so it occupies small amount of spectrum and it is easily accommodated in TDMA/EDMA scheme.

For data services, the time slots need to be aggregated to provide higher data rate.

This is done in GPRS/EDGE - not very efficient way for data transmission.

Since communication networks are moving towards all IP (data) TDMA is bound to be phased out.