

Multiplexing

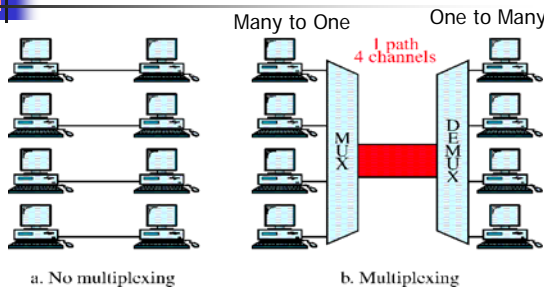
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<http://www.cpe.ku.ac.th/~anan>
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 Kasetsart University, Bangkok, Thailand

Why multiplexing?

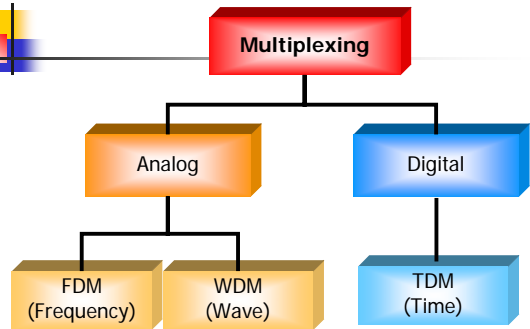
- Media Sharing
 - Medium Transmission Capacity
 - High bandwidth media (coax, optical fiber)
- Cost-effective
- Medium Transmission Cap > data rate required

Multiplexing vs. No Multiplexing

Terms:
 • Path
 • Channel



Multiplexing

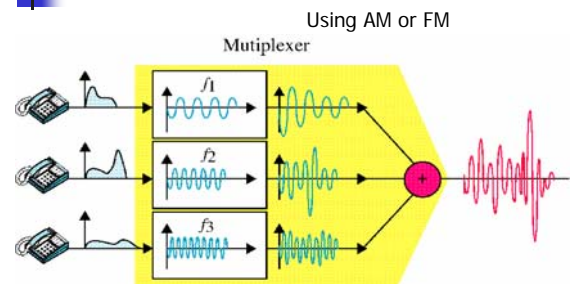


FDM

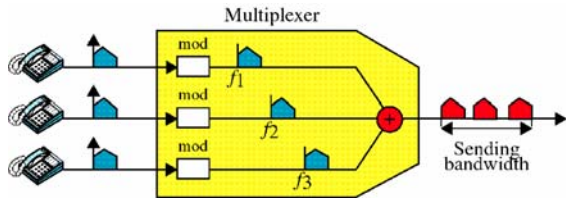
Terms:
 • Guard band



FDM, Time Domain

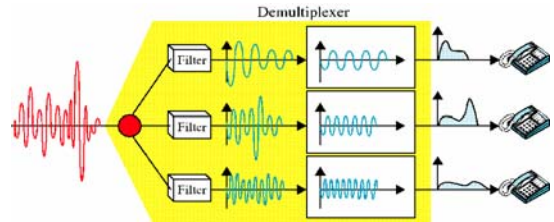


Multiplexing, Frequency Domain



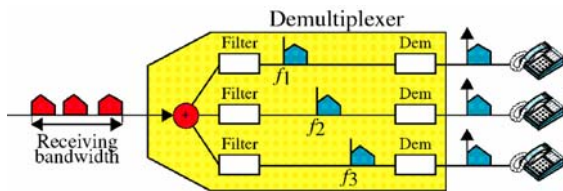
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Demultiplexing, Time Domain



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Demultiplexing, Freq. Domain



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Mux – Example I

Question

We need to combine three voice channels (BW = 4KHz) into a link with a bandwidth of 12 KHz, from 20 to 32 KHz.

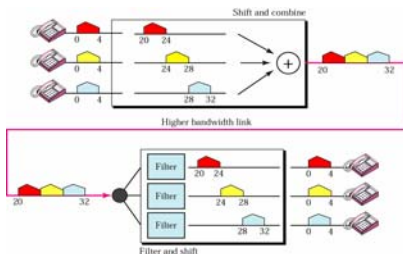
Show the configuration using the frequency domain without the use of guard bands.

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Mux – Example I

Solution

Shift (modulate) each of the three voice channels to a different bandwidth



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Mux – Example II

Question

Five channels, each with a 100-KHz bandwidth, are to be multiplexed together.

What is the minimum bandwidth of the link if there is a need for a **guard band of 10 KHz** between the channels to prevent interference?

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Mux – Example II

Solution For five channels, we need at least four guard bands. This means that the required bandwidth is at least
 $5 \times 100 + 4 \times 10 = 540 \text{ KHz}$



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Mux – Example III

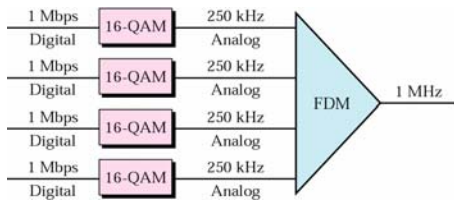
Question Four data channels (digital), each transmitting at 1 Mbps, use a satellite channel of 1 MHz.

Design an appropriate configuration using FDM

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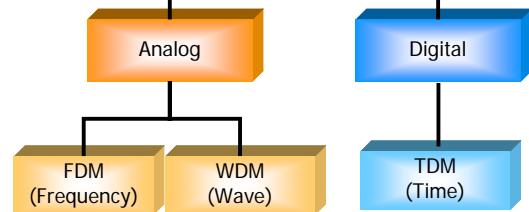
Mux – Example I

Solution The satellite channel (1 MHz) is analog. For four channels, BW for each channel = 250KHz. By using 16-QAM, 4 bits are modulated to 1 Hz.



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Multiplexing



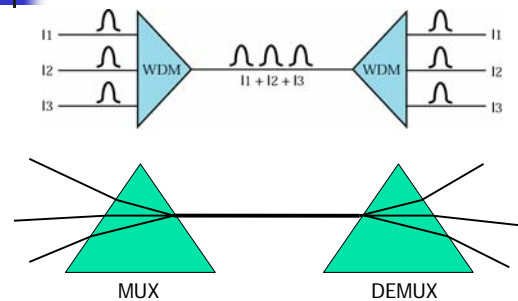
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WDM

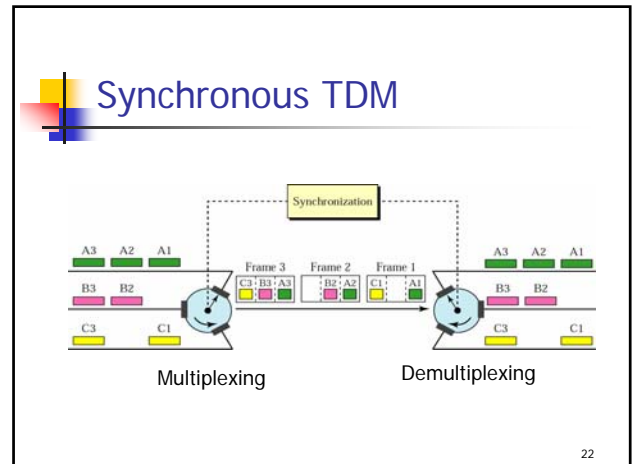
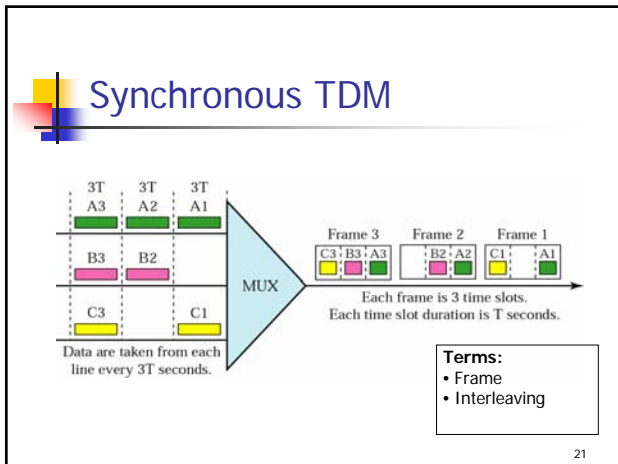
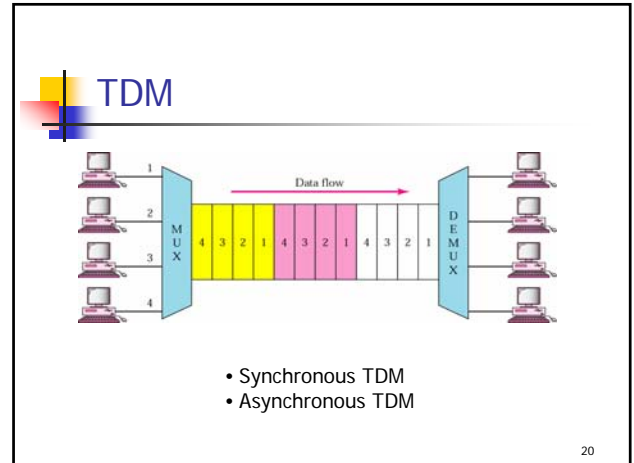
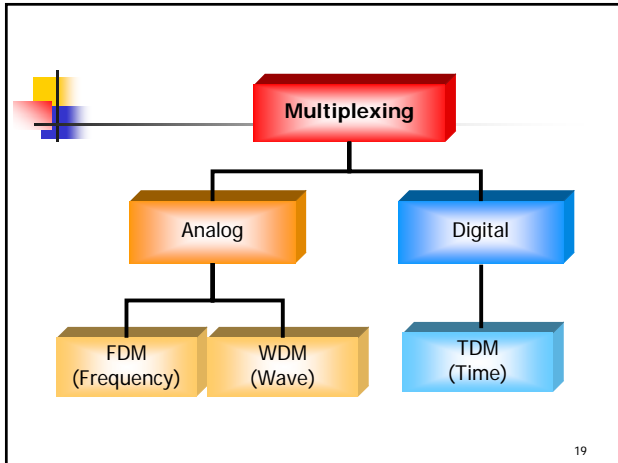
- Same as FDM but very higher frequency
- Light signal
- Optical fiber

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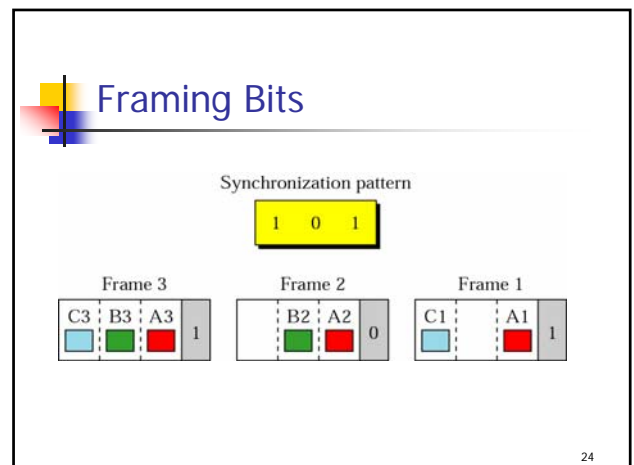
WDM



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-
- Synchronous TDM**
- Time slot is fixed
 - Small overhead (no identification for each slot)
 - How about the slot synchronization?
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TDM – Example I

Question

Four sources, each creating 250 characters per second.
If the interleaved unit is a character and 1 synchronizing bit is added to each frame

- Find
- 1) the data rate of each source
 - 2) the duration of each character in each source
 - 3) the frame rate
 - 4) the duration of each frame
 - 5) the number of bits in each frame
 - 6) the data rate of the link.

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TDM – Example I

Solution

1. The data rate of each source = 250 characters/s = 2000 bps = 2Kbps.
2. The duration of a character is $1/250$ s, or 4 ms.
3. The link needs to send 250 frames per second.
4. The duration of each frame is $1/250$ s, or 4 ms.
5. Each frame is $4 \times 8 + 1 = 33$ bits.
6. The data rate of the link is 250×33 , or 8250 bps.

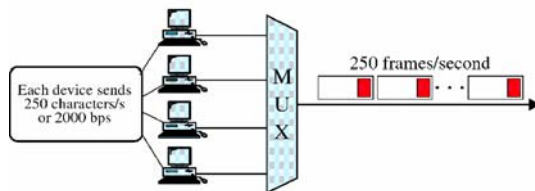
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TDM – Example I

$$8250 \text{ bps} = 250 \text{ frames/second} \times 33 \text{ bits/frame}$$

or

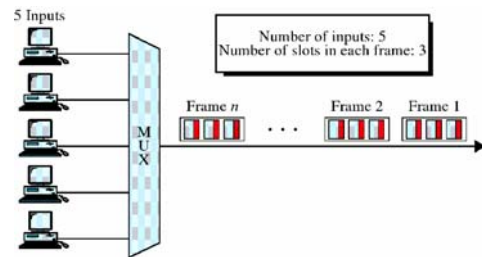
$$8250 \text{ bps} = 4 \times 2000 \text{ bps} + 250 \text{ synchronization bps}$$



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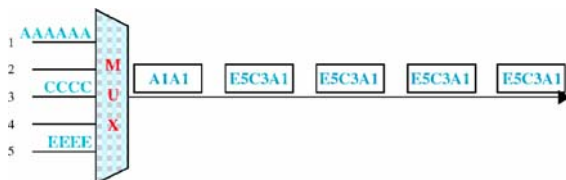
Asynchronous TDM (statistical TDM)

- Terms:**
- Frame
 - Address needed
 - Synchronous= fixed



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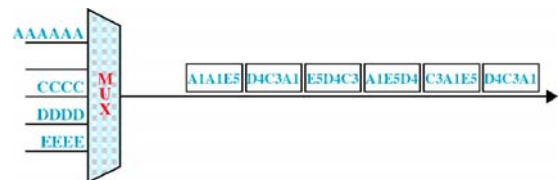
Frames and Addresses



a. Only three lines sending data

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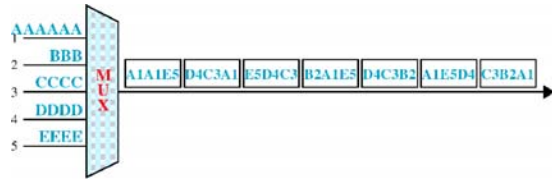
Frames and Addresses



b. Only four lines sending data

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Frames and Addresses



c. All five lines sending data

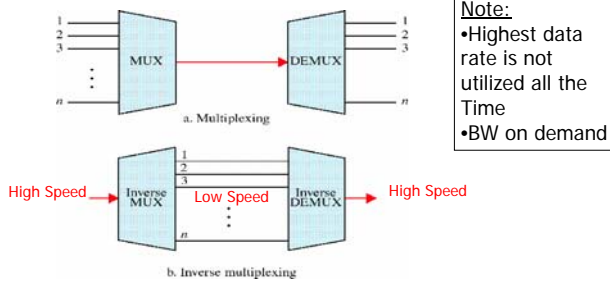
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Asynchronous TDM

- For case b and c ($\#input > \#slot$)
 - Data arrives faster
 - Buffer is needed
- Overhead
 - Addressing cause high overhead
- Being used when big time slot

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Multiplexing and Inverse Multiplexing



Note:
 • Highest data rate is not utilized all the Time
 • BW on demand

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Multiplexing Application (The telephone system)

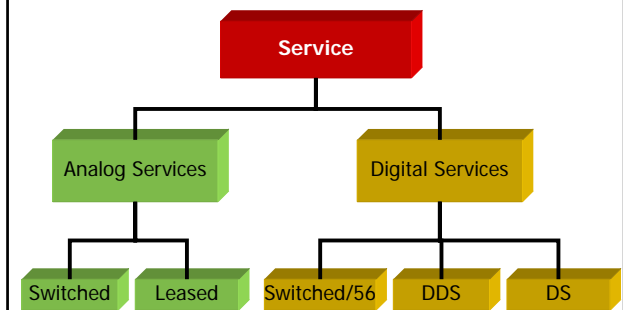
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Telephone Network

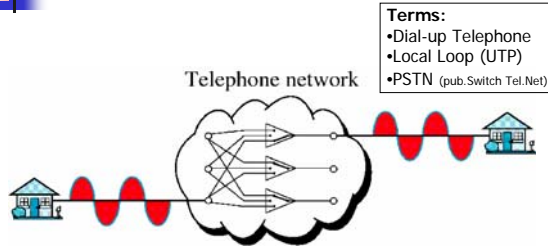


Terms:
 • Service Line
 • Common carrier

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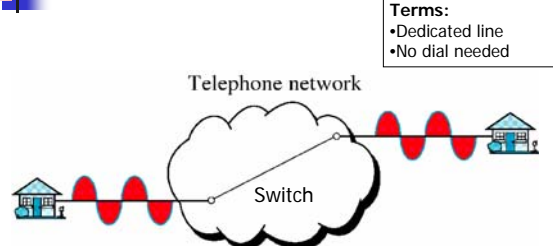


Analog Switched Service



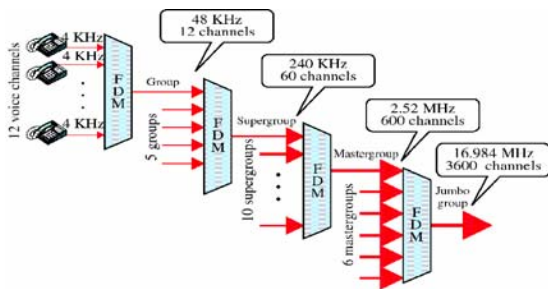
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Analog Leased Service



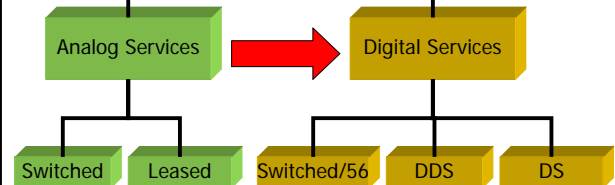
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Analog Hierarchy



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Service

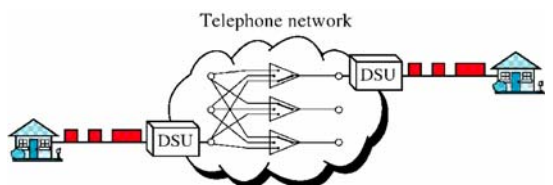


Digital Services

- → move from Analog
- Less sensitive than analog
 - Noise is analog
 - Digital signal + Analog noise
 - Lower cost (only 2-3 voltage level checks)
 - Lower equipment cost

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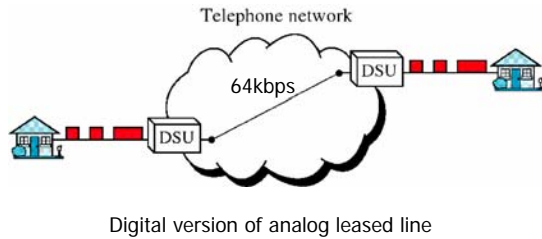
Switched/56 Service



•DSU=digital service unit (instead of modem) change data rate →56Kbps
 •DSU→expensive Why need?

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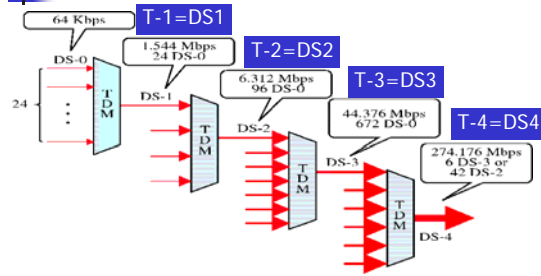
Digital Data Service (DDS)



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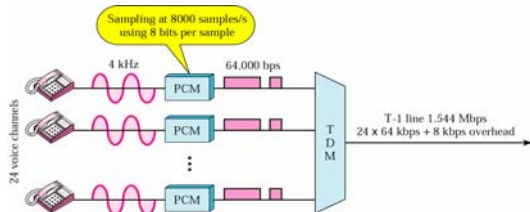
Digital Signal (DS) Hierarchy

Terms:
• T-Line → Europe (E-Line)



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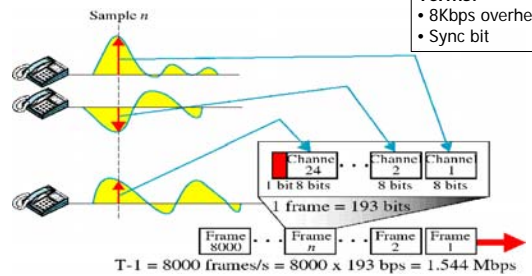
T-1 line for multiplexing telephone lines



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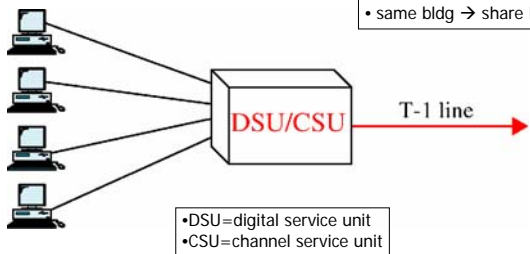
T-1 Frame Structure

Terms:
• 8Kbps overhead
• Sync bit



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Fractional T-1 Line



• DSU=digital service unit
• CSU=channel service unit

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T Lines

Service	Line	Rate (Mbps)	Voice Channels (64 Kbps)
DS-1	T-1	1.544	24
	T1C	3.152	48
DS-2	T-2	6.312	96
DS-3	T-3	44.736	672
DS-4	T-4	274.176	4032

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E Lines

- ITU-T Standard
- Europe and also Thailand

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E Lines

Line	Rate (Mbps)	Voice Channels (64 Kbps)
E-1	2.048	30
E-2	8.448	120
E-3	34.368	480
E-4	139.264	1920
E-5	565.148	7680

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E Lines

รายละเอียด	2.4, 4.8, 9.6 Kbps	64 Kbps	2 Mbps
ค่าติดตั้ง/ขอใช้	6,700 บาท/วงจร	8,000 บาท/วงจร	45,000 บาท/วงจร
ค่าเช่ารายเดือน (ภายในชุมสายเดียวกัน)	1,300 บาท	3,000 บาท	25,000 บาท
-ผ่าน 2 ชุมสาย	2,000 บาท	6,000 บาท	50,000 บาท
-ผ่าน 3 ชุมสายหรือมากกว่า	3,000 บาท	9,000 บาท	75,000 บาท

บริการสายเช่าของเทลคอมเอเชีย (ที่มา : องค์กรโทรศัพท์แห่งประเทศไทย)

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OC (Optical Carrier in SONET)

Line	Rate (Mbps)	Voice Channels (64 Kbps)
OC-1	51.480	630
OC-3	155.520	1890
OC-12	622.080	7,560
OC-24	1,244.160	15,120
OC-48	2,488.320	30,240
OC-192	9,953.280	120,960

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Lease Line (Update : 19/11/2003)

Lease Line Packages				
	ค่าแรกเข้า (บาท)	ค่าติดตั้ง	จำนวนใช้งาน (ชั่วโมง)	ค่า Media + ค่าเน็ต
nbn.com Unlimit³ ความเร็ว 64 Kbps	4000 (ฟรีถึงสิ้นปี46)	2000(ฟรีถึงสิ้นปี 46)	Unlimit	3000+3200=6200
nbn.com Unlimit³ ความเร็ว 128 Kbps	4000 (ฟรีถึงสิ้นปี46)	2000(ฟรีถึงสิ้นปี 46)	Unlimit Local	6000+4750=10750
nbn.com Unlimit³ ความเร็ว 256 Kbps	4000 (ฟรีถึงสิ้นปี46)	2000(ฟรีถึงสิ้นปี 46)	Unlimit Local	11300+7000=18300
AsiaNet.com Unlimit³ ความเร็ว 128 Kbps	-	-	Unlimit Local	15700

http://www.jnetgame.com/nethighspeed.html#compare_adsl

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Assignment

- Finding up-to-date details for Internet Access
 - 56 K Modem Access
 - ADSL Access
 - Cable Modem
 - ISDN Access
 - Lease Line
 - WLAN Access

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Assignment

- How does the technology work?
 - Summarize each technology
 - Including pictures
- Finding the cost of applying
 - In Thailand / compare to other countries
 - Summarize in one page
 - Comparison table for each technology
- Comparison of all technologies
 - Summarize in 1-2 pages
 - Technical issues; usage issues; etc.
- References
- Not more than 12 pages

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