

TEE 843 – Sistem Telekomunikasi

Multiplexing dan Multiple-Access



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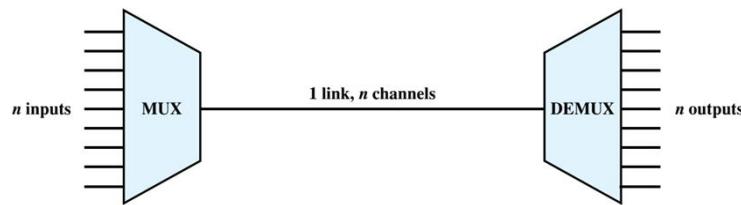
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Jurusan Teknik Elektro FT-Unimal
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Outline

- Multiplexing-Demultiplexing
 - Prinsip Dasar Multiplexing (FDM dan TDM)
 - Multiplexing Standar (E1, T1, PDH, SDH/Sonet)
 - Optical Multiplexing (WDM dan DWDM)
- Duplexing
- Multiple-Access
 - FDMA, TDMA, CDMA

Multiplexing

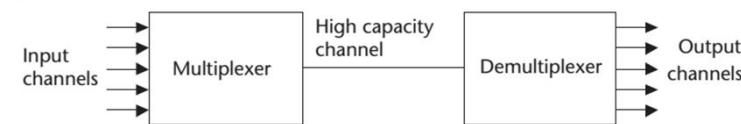


- **Multiplexing** adalah suatu proses penggabungan beberapa sinyal utk ditransmisikan secara simultan melalui satu media/link transmisi.
- Pada **pengirim** dilakukan ***multiplexing***, alatnya dinamakan ***multiplexer***.
- Sebaliknya, pada **penerima** dilakukan ***demultiplexing***, alatnya dinamakan ***demultiplexer***

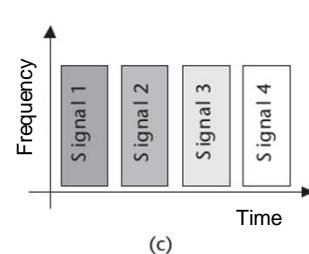
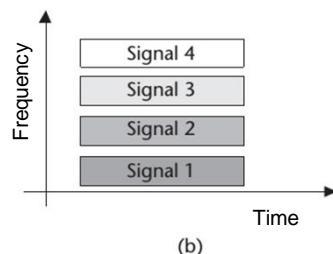
Multiplexing (lanjutan)

- Multiplexing-demultiplexing diimplementasikan pada jaringan transmisi/trunk/transport/backbone.
- Dua jenis dasar multiplexing:
 1. *Frequency-Division Multiplexing* (FDM)
 2. *Time-Division Multiplexing* (TDM)
- Pada *Frequency-Division Multiplexing* (FDM), pembagian kanal dilakukan dlm frekuensi, dimana setiap sinyal menduduki range frekuensi yg berbeda dlm kanal tsb.
- Pada *Time-Division Multiplexing* (TDM), setiap sinyal menduduki interval waktu yg berbeda dlm kanal tsb.

Multiplexing (lanjutan)



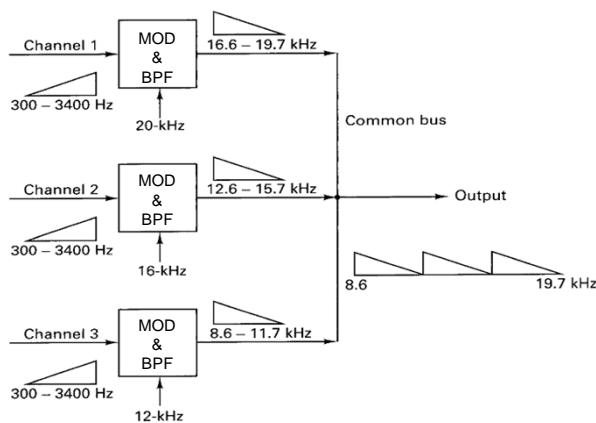
(a)



(a) Konsep dasar multiplexing/demultiplexing, (b) FDM, (c) TDM

Frequency-Division Multiplexing (FDM)

- Utamanya dipakai pada **komunikasi analog**, tp bisa juga dipakai pada komunikasi digital.
- Berikut ini adalah contoh sederhana FDM:



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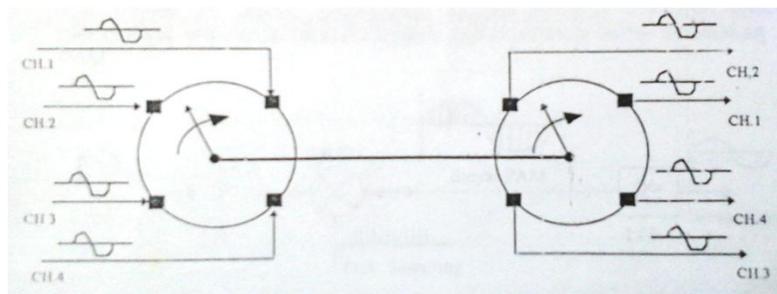
FDM Standar

| Level | Jumlah kanal suara |
|-------------------|-----------------------------|
| Pre-group (PG) | 3 kanal |
| Basic Group (BG) | $4 \times 3 =$ 12 kanal |
| Super Group (SG) | $5 \times 12 =$ 60 kanal |
| Master Group (MG) | $16 \times 60 =$ 960 kanal |
| | $20 \times 60 =$ 1200 kanal |

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Time-Division Multiplexing (TDM)

- Dipakai pada **komunikasi digital**.
- Pada komunikasi suara/telepon, kanal-kanal yang dimultiplexkan adalah kanal suara PCM (64 kbps).
- Cara kerja TDM dpt diilustrasikan oleh prinsip komutator berikut ini:



TDM Standar

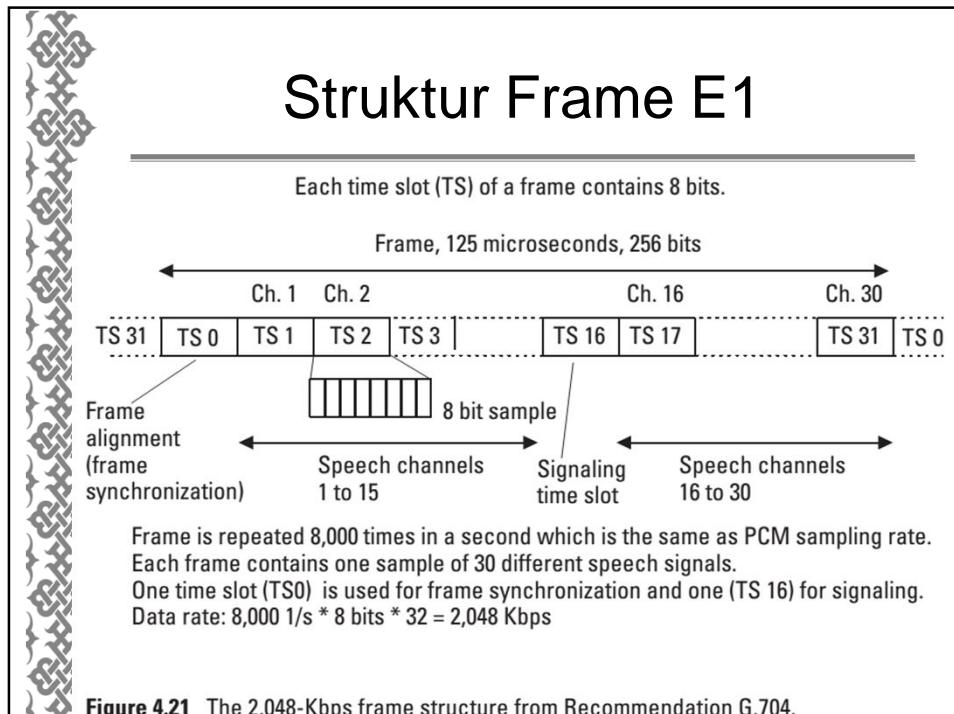
- E1 (*2-Mbps PCM frame*)
- T1 (*1.5-Mbps PCM frame*)
- PDH (*Plesiochronous Digital Hierarchy*)
- SONET (*Synchronous Optical Network*)
- SDH (*Synchronous Digital Hierarchy*)

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2-Mbps PCM frame (E1)

- Kecepatannya **2,048 Mbps**, merupakan **kecepatan primer (primary rate)** pada jaringan telekomunikasi **standar Eropa**, yg kemudian jadi standar ITU-T.
- Dipakai utk mentransmisikan kanal-kanal suara (*speech channels*) dan kanal-kanal Broadband-ISDN (B-ISDN).
- Dikenal dgn nama **E1** atau **PCM 30**.
- Ukuran frame adlh 256 bit yg terdiri dari 32 time slot (30 TS utk 30 kanal suara + 2 TS utk sinkronisasi & signaling), dimana tiap TS berisi 8 bit.
- Laju frame adlh 8.000 frame/sekon, sehingga data rate menjadi $8.000 \times 256 = 2.048.000$ bps.

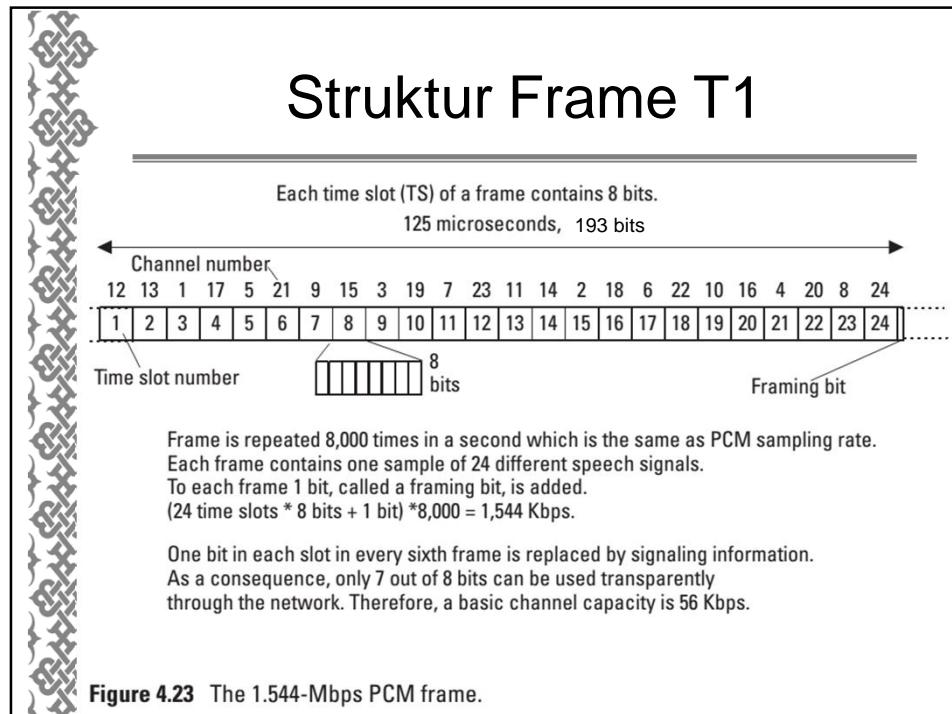
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1.5-Mbps PCM frame (T1)

- Kecepatannya **1,544 Mbps**, merupakan **kecepatan primer (primary rate)** pada jaringan telekomunikasi standar Amerika dan Jepang.
- Dipakai utk mentransmisikan kanal-kanal suara (*speech channels*) dan kanal-kanal Broadband-ISDN (B-ISDN).
- Dikenal dgn nama **T1** atau **DS1** atau **PCM 24**.
- Ukuran frame adlh 193 bit yg terdiri dari 24 time slot (utk 24 kanal suara) + 1 bit utk framing. Dimana tiap TS berisi 8 bit.
- Laju frame adlh 8.000 frame/sekon, shg data rate menjadi $8.000 \times (24 \times 8 \text{ bit} + 1 \text{ bit}) = 1.544.000 \text{ bps}$.

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Plesiochronous Digital Hierarchy (PDH)

- *Plesiochronous Digital Hierarchy (PDH)* adlh standar hirarki multiplexing untuk transmisi digital orde lbh tinggi.
- Standar PDH Eropa berbeda dgn standar PDH Amerika.
- Level-level multiplexing pd PDH standar Eropa adlh E0, E1, E2, E3, dan E4.
- Level-level multiplexing pd PDH standar Amerika adlh DS1, DS1C, DS2, DS3, dan DS4.

PDH Standar Eropa

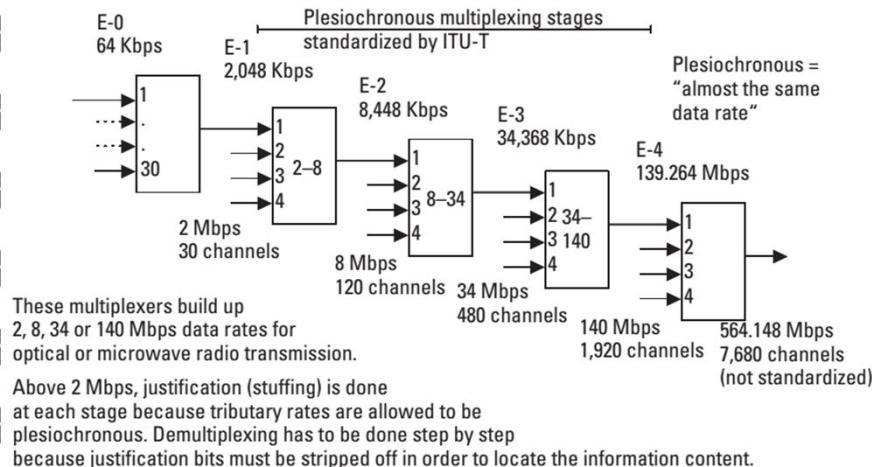
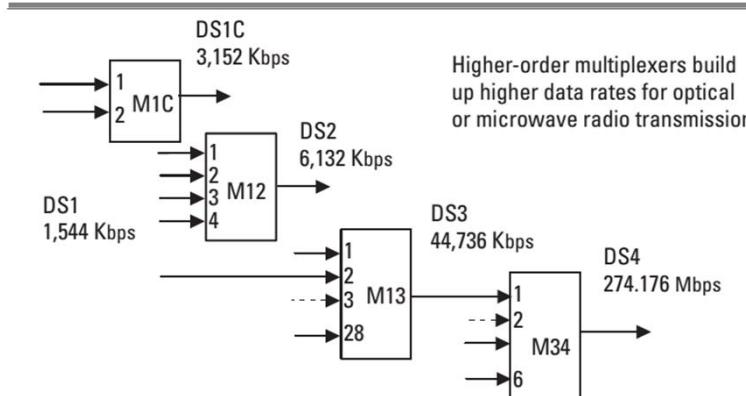


Figure 4.24 The PDH (European standard).

PDH Standar Amerika Utara



Above 1.5 Mbps, justification (stuffing) is done at each stage because tributary rates are allowed to be plesiochronous. Demultiplexing has to be done step by step because justification bits must be stripped off in order to locate the information content.

Figure 4.25 North American PDH.

Media trasmisi utk PDH

- Berikut ini adlh PDH Standar Eropa yg dipakai di Indonesia beserta media transmisi yg digunakan.

| Level | Bit rate | Jlh kanal | Media |
|------------------|----------|------------|---------------------|
| Voice Channel | 64 kbps | 1 kanal | twisted-pair |
| Multiplex orde 1 | 2 Mbps | 30 kanal | t-pair, coax, radio |
| Multiplex orde 2 | 8 Mbps | 120 kanal | t-pair, coax, radio |
| Multiplex orde 3 | 34 Mbps | 480 kanal | t-pair, coax, radio |
| Multiplex orde 4 | 140 Mbps | 1920 kanal | radio, optic |
| Multiplex orde 5 | 565 Mbps | 7680 kanal | optic |

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Synchronous Optical Network (SONET)

- Synchronous Optical Network* (SONET) adlh standar multiplexing yg dikembangkan oleh ANSI dan digunakan di Amerika.
- The *synchronous transport signal level 1* (STS-1) is the basic SONET module that corresponds to STM-1 of SDH. These modules have a bit rate of 51.840 Mbps and they are multiplexed synchronously into higher-order signals STS-N.
- Each STS-N signal has a corresponding optical signal called an *optical carrier* (OC-N) for optical transmission.

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Synchronous Digital Hierarchy (SDH)

- *Synchronous Digital Hierarchy* (SDH) adlh standar multiplexing yg dibuat oleh ITU-T dan diadopsi oleh ETSI utk dipakai di Eropa.
- The transmission data streams of SDH are called *synchronous transport modules* (STMs) and they are exact multiples of STM-1 at the 155.52-Mbps data rate.
- STM-1 data are simply byte interleaved with other STM-1 data streams to make up a higher transmission data rate (STM-4).
- Byte interleaving means that, for example, an STM-4 signal contains a byte (8 bits) from the first STM-1 tributary, then from the second, third, and fourth tributaries, and then again from the first one.
- The demultiplexer receives all STM-1 frames independently.

SDH (lanjutan)

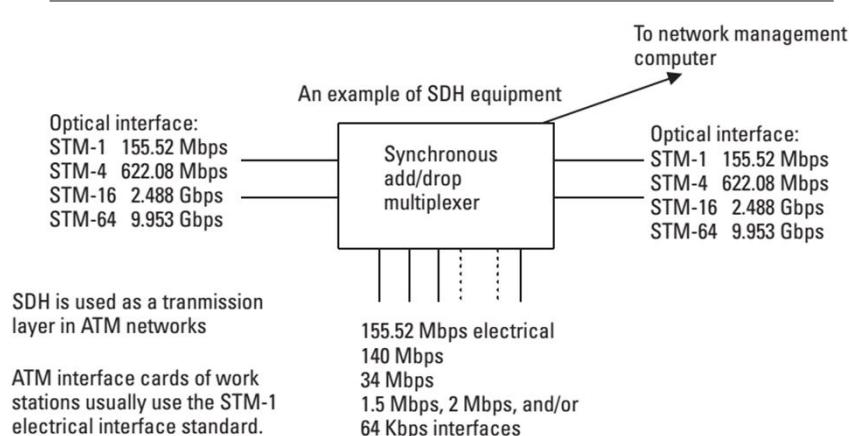


Figure 4.26 The synchronous digital hierarchy of ETSI.

SONET vs SDH

- Secara prinsip SONET mirip dan kompatibel dgn SDH.
- Keduanya semula dirancang utk transmisi kanal-kanal PCM 64 kbps.

Table 4.3

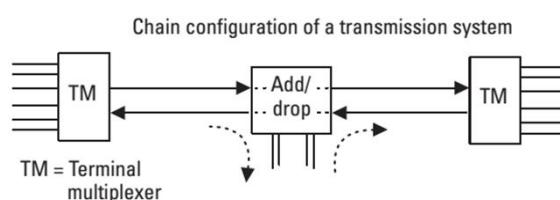
Data Rates of SONET (United States) and Corresponding SDH Data Streams (Europe)

| OC-N Optical Carrier Level | STS-N Electrical Level | Data Rate (Mbps) | SDH STM-N |
|----------------------------|------------------------|------------------|-----------|
| OC-1 | STS-1 | 51.84 | |
| OC-3 | STS-3 | 155.52 | STM-1 |
| OC-12 | STS-12 | 622.08 | STM-4 |
| OC-24 | STS-24 | 1244.16 | |
| OC-48 | STS-48 | 2488.32 | STM-16 |
| OC-192 | STS-192 | 9953.28 | STM-64 |

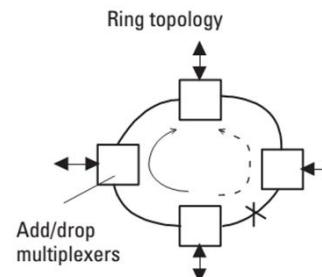
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Multiplexer dlm Jaringan

Multiplexers combine lower rate data signals into a higher rate aggregate signal



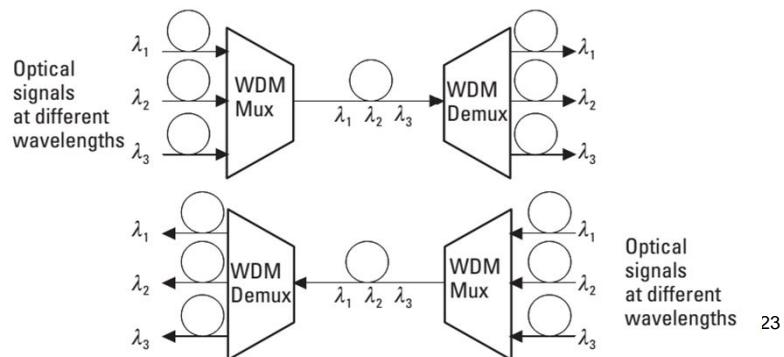
Add/drop multiplexers add or drop out digital tributary signals to/from the aggregate data stream.



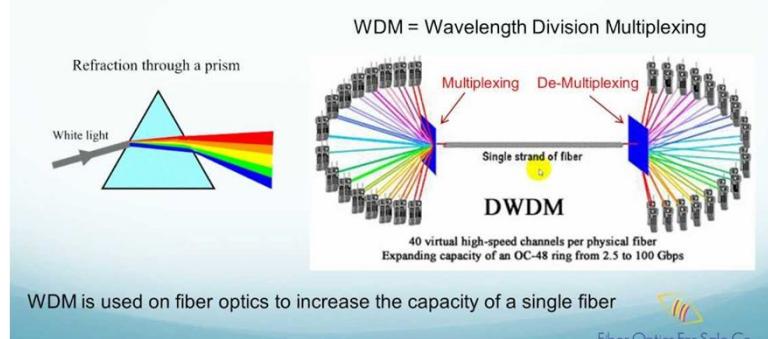
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Optical Multiplexing (WDM dan DWDM)

- The *wavelength-division multiplexing* (WDM) uses an optical coupler to combine optical signals (WDM multiplexer) and optical filters (WDM demultiplexer) to separate optical signals at the receiving end.



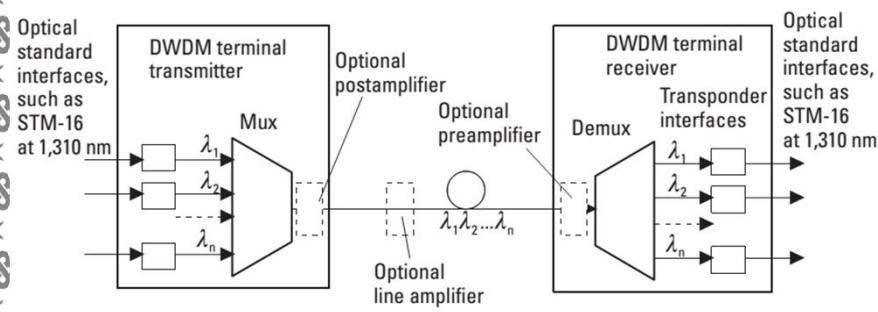
WDM dan DWDM (lanjutan)



DWDM = Dense Wavelength Division Multiplexing

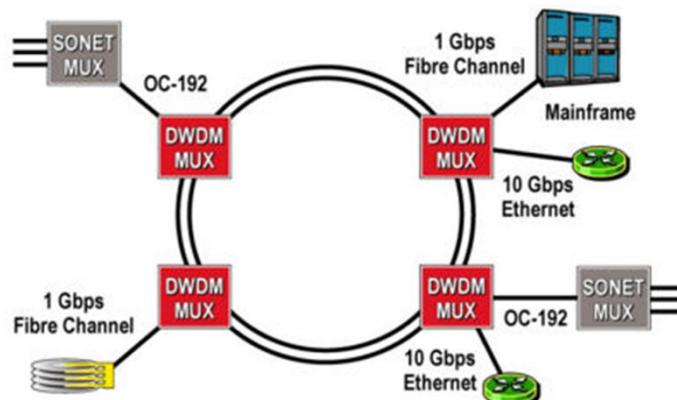
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WDM dan DWDM (lanjutan)



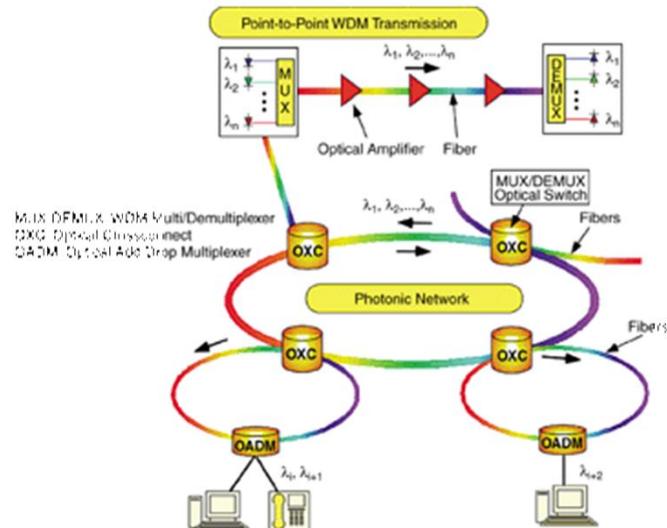
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Optical Ring Network



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Photonic Network



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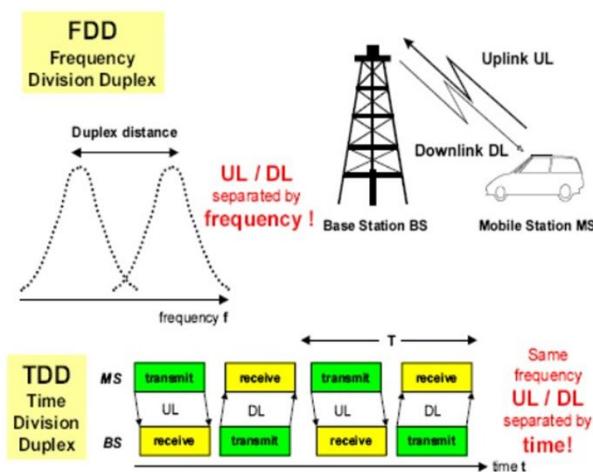
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Duplexing

- Duplexing is allowing communication in opposite directions simultaneously (bidirectional).
- Ingat transmisi dupleks: half-duplex dan full-duplex.
- Dua jenis duplexing:
 - *Time-division duplexing* (TDD)
 - *Frequency-division duplexing* (FDD)
- TDD is the application of *time-division multiplexing* to separate forward/downlink and reverse/uplink signals.
- FDD is the application of *frequency-division multiplexing* to separate forward/downlink and reverse/uplink signals.

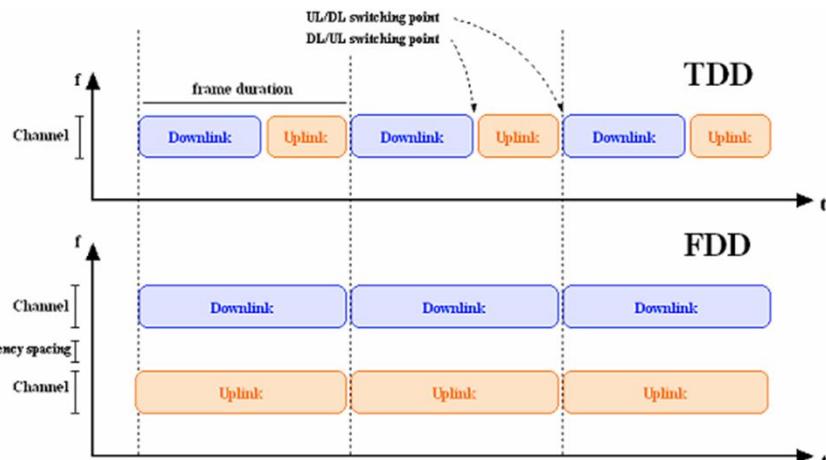
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Duplexing (lanjutan)



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Duplexing (lanjutan)



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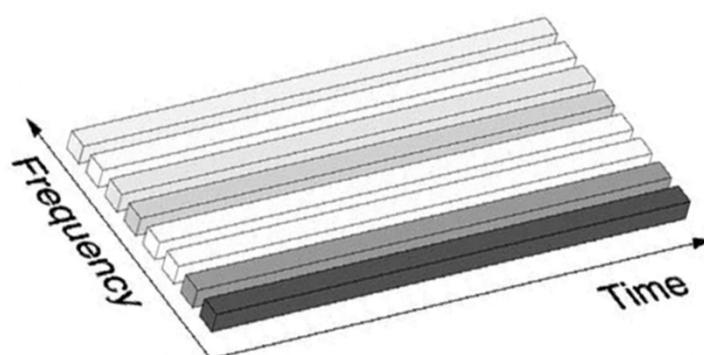
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Teknik Multiple-Access

- FDMA (Frequency Division Multiple Access)
- TDMA (Time Division Multiple Access)
- CDMA (Code Division Multiple Access)
- SDMA (Space Division Multiple Access)

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FDMA



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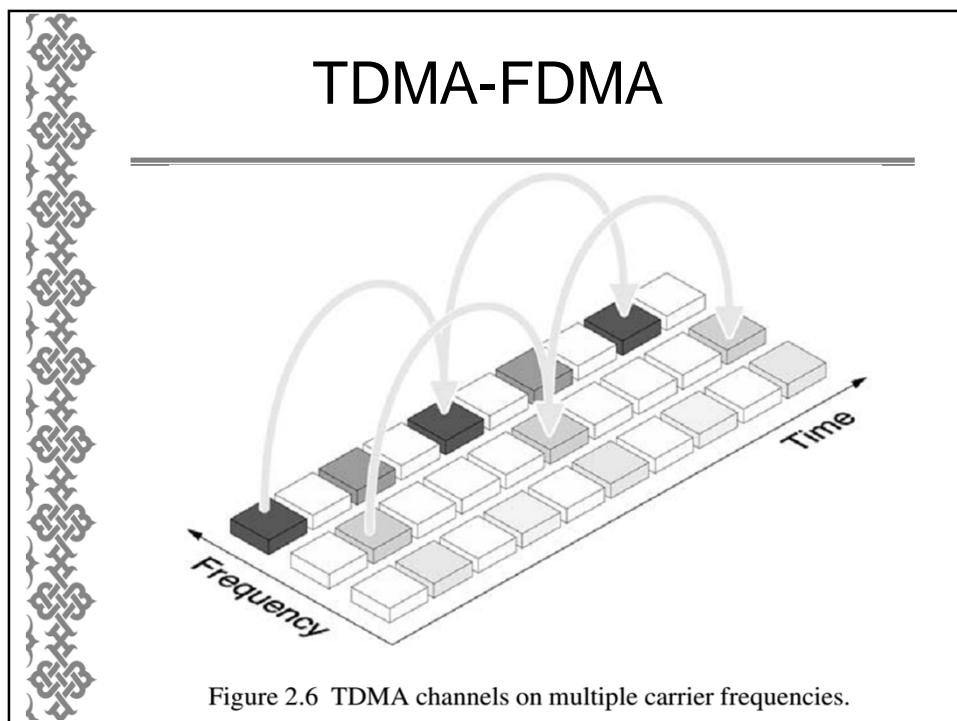
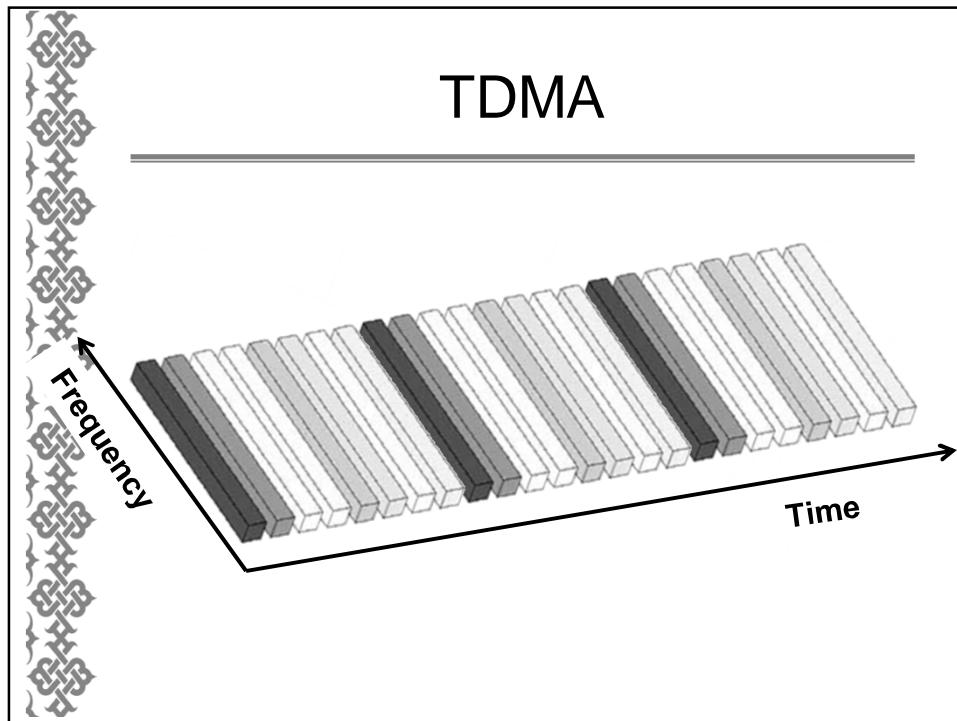
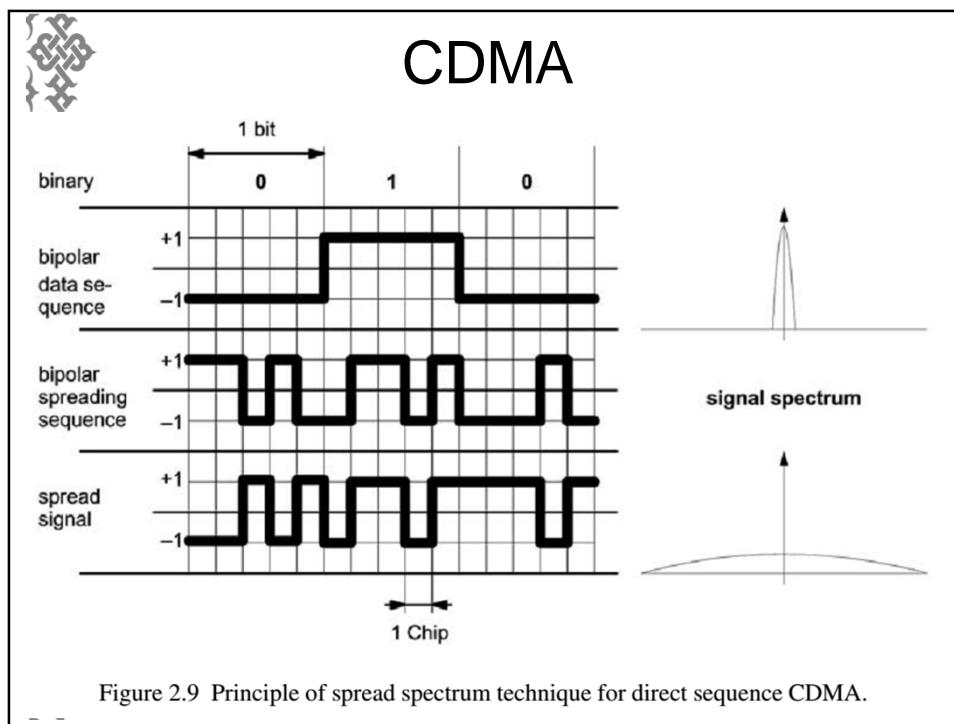
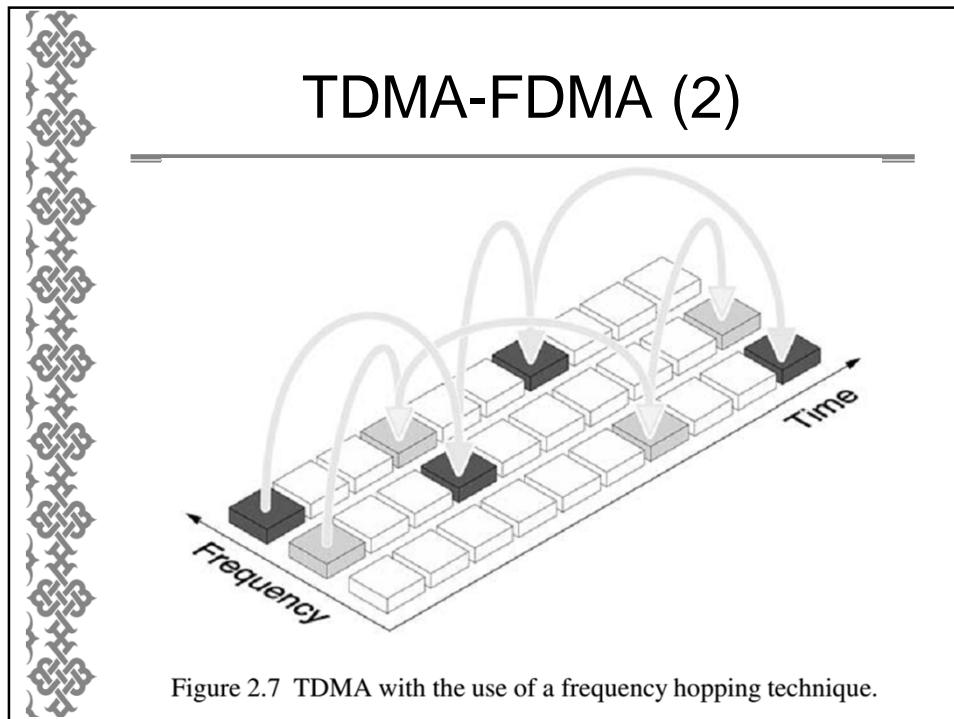


Figure 2.6 TDMA channels on multiple carrier frequencies.



CDMA (lanjutan)

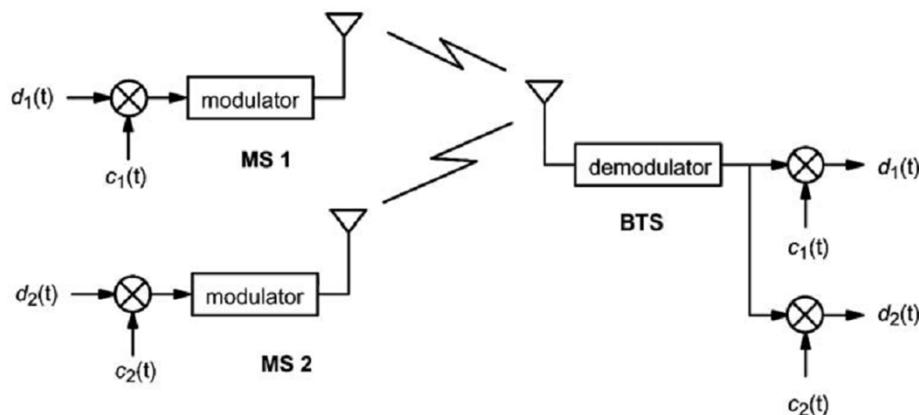


Figure 2.10 Simplified scheme of CDMA (uplink).

Multiple-Acess (summary)

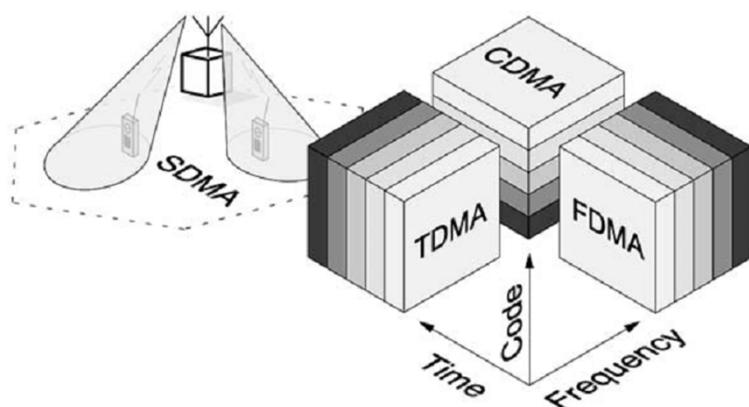


Figure 2.4 Multiple access procedures.

PR-7

- 1) Explain what is multiplexing? What are the main two multiplexing methods and how do they operate?
- 2) Explain the structure of a 2-Mbps PCM frame.
- 3) Explain the structure of a 1.5-Mbps PCM frame.
- 4) Explain what is PDH?
- 5) What is SDH and what advantages does it provide over PDH?
- 6) Explain what is duplexing? What are the main two duplexing methods and how do they operate?
- 7) Explain what is multiple-access? What are the main four multiple-access techniques and how do they operate?

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Spirit Minggu Ini

- *Maka apabila kamu telah selesai (dari sesuatu urusan), kerjakanlah dengan sungguh-sungguh (urusan) yang lain, dan hanya kepada Tuhanmulah hendaknya kamu berharap.*
(Q.S. Alam Nasyrah [94]: 7 – 8)

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Sekian, ada pertanyaan?
Terima kasih, semoga berkah.

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