12. Teknologi Jaringan Akses

Muhammad Daud Nurdin
mdaud@unimal.ac.id, syechdaud@yahoo.com

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Jaringan Telekomunikasi:
Jaringan Akses dan Jaringan Transmisi

Figure 2.20 Overview of the public switched telecommunications network.
Figure 2.20 Overview of the public switched telecommunications network.
Access Network

• The access network provides the connection between the subscriber’s premises and the local exchange.
• This connection is commonly referred to as the last mile.
• Technologies used in the access network are:
  – the basic local loop, the fixed wireless local loop, and the digital subscriber loop (forming the PSTN),
  – cellular (forming the PLMN),
  – fiber-based techniques such as fiber to home (FTTH),
  – other broadband access techniques.
Teknologi Jaringan Akses

1. **Local loop** pada PSTN
   - Leased Line
   - Voice-Band Modem
   - ISDN
   - DSL
   - Fiber Cable Access

2. Cable TV Network

3. **LAN** (Local Area Network)

4. Wireless Access
Jaringan Akses pada PSTN

• Jaringan akses/lokal pada PSTN disebut *local loop*, *dc loop*, atau *subscriber loop*.
• Pada awalnya hanya menyediakan layanan komunikasi suara (*voice communications*) → *basic local loop*.
• Lalu berkembang menyediakan layanan:
  – *Leased Line* (saluran yg disewakan)
  – *Voice-Band Modems* (modem pita frekuensi suara)
  – *Integrated Services Digital Network (ISDN)*
  – *Digital Subscriber Line (DSL)*
• Klasifikasi dan istilahnya di Indonesia:
  – Jarlokat (jaringan lokal akses tembaga)
  – Jarlokar (jaringan lokal akses radio)
  – Jarlokaf (jaringan lokal akses fiber)
Arsitektur Jarlokat

MDF = Main distribution frame;  
DP = Distribution point;  
RK = Rumah kabel;  
KTB = Kotak terminal batas
Leased Line

• The **leased line** is connected all the time, but **dial-up** or switched lines are connected only on demand.

• Leased lines can be used for **voice** (telephone), **data** or Internet services.

• Leased lines are available at speeds of 64 kbit/s, 128 kbit/s, 256 kbit/s, 512 kbit/s, 1 Mbit/s, 2 Mbit/s, 4 Mbit/s, 8 Mbit/s, 16 Mbit/s, T1(1.544 Mbit/s), or E1(2.048 Mbit/s).
Leased Line (lanjutan)

Figure 6.24 Regional and long-distance leased lines.
Voice-Band Modem

• The word **modem** comes from the combination of the two devices, **modulator** and **demodulator**.

• **Modulation** converts a digital signal into an analog signal for transmission through a channel, and **demodulation** performs the conversion back to the original digital baseband data signal.

• **Voice-band modems** are needed when an analog voice channel of the telephone network is used for **data transmission**.

• The **frequency band** of the voice channel is 300 to 3,400 Hz and the baseband digital information is transferred to this band through CW modulation.
Voice-Band Modem (lanjutan)

Modem = Modulator + Demodulator

Modem converts the digital signal into an analog signal for transmission through the voice channel of PSTN.

The amplitude, frequency, and/or phase of the carrier wave carry the values of the digital signal to the receiving end.

The demodulator of the modem converts amplitude, frequency, and/or phase into the values of the digital signal.

DTE = Data terminal equipment
DCE = Data circuit terminating equipment or data communications equipment
PCM = Pulse code modulation

Figure 6.13 Modem link over the PSTN.
Integrated Services Digital Network (ISDN)

- **ISDN** is a set of communication standards for simultaneous digital transmission of voice, video, data, and other network services over the traditional circuits of the PSTN.
- The key feature of ISDN is that it integrates **speech** and **data** on the same lines.
- The ISDN provides switched end-to-end digital $n\times64$ kbps circuits that we can use for voice or data.
  - Basic rate interface (BRI) = $2B + D = (2\times64 + 16)$ kbps = 144 kbps
  - Primary rate interface (PRI)
    - Eropa, PRI = $30B + 2D = (32\times64)$ kbps = 2,048 Mbps
    - Amerika, PRI = $23B + D + framing = (24\times64 + 8)$ kbps = 1,544 MBps
ISDN (lanjutan)

**Basic rate interface, BRI, 2B+D:**
Two bearer channels (B) at 64 Kbps and one signaling channel (D) at 16 Kbps, 2B+D, totally 144 Kbps. The framing information increases data rate on a subscriber line to 160 Kbps.

Maximum 8 subscriber devices may be connected to NT and two of them may communicate at the same time.

**Primary rate interface, PRI:**
European PRI: 30 bearer channels, one signaling channel and framing, all at 64 Kbps make up data rate of 2.048 Mbps. Framing structure is the same as in ordinary 2 Mbps PCM. American PRI: 23B+D plus framing, 1.544 Mbps.
Digital Subscriber Line (DSL)

- In the DSL (*digital subscriber line* or *digital subscriber loop*) techniques, **data** and **speech** are separated at the local exchange site.
- The **speech** portion is connected to the switching (PSTN).
- The **data** portion is connected to the data network for Internet access.
- **Applications of DSL**: remote access to data center, Internet access, and interconnection of LANs.
- Term **xDSL** refers to different variations of DSL, such as ADSL, HDSL, and RADSL.
DSL (lanjutan)

Figure 6.16 DSL in the local loop.

DSL = digital subscriber line
DSLAM = DSL access multiplexer
ISP = Internet service provider
PSTN = Public switched telephone network
## DSL (lanjutan)

<table>
<thead>
<tr>
<th>DSL Technology</th>
<th>Reach (km)</th>
<th>Downstream Data Rate</th>
<th>Upstream Data Rate</th>
<th>Analog Phone</th>
<th>Market</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDSL</td>
<td>8</td>
<td>144 Kbps</td>
<td>144 Kbps</td>
<td>No</td>
<td>Residential</td>
</tr>
<tr>
<td>G.lite ADSL</td>
<td>5</td>
<td>1.5 Mbps</td>
<td>640 Kbps</td>
<td>Yes</td>
<td>Residential</td>
</tr>
<tr>
<td>HDSL</td>
<td>4</td>
<td>2/1.5 Mbps</td>
<td>2/1.5 Mbps</td>
<td>No</td>
<td>SME*</td>
</tr>
<tr>
<td>SDSL, G.shdsl</td>
<td>5–6</td>
<td>2.3 Mbps</td>
<td>2.3 Mbps</td>
<td>No</td>
<td>SME</td>
</tr>
<tr>
<td>G.dmt ADSL</td>
<td>3</td>
<td>...8 Mbps</td>
<td>...1.5 Mbps</td>
<td>Yes</td>
<td>Residential</td>
</tr>
<tr>
<td>VDSL</td>
<td>0.1–2</td>
<td>...52 Mbps</td>
<td>6 Mbps</td>
<td>Yes</td>
<td>Residential</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(34 Mbps)</td>
<td>(34 Mbps)</td>
<td></td>
<td>SME</td>
</tr>
</tbody>
</table>

*SME = small and medium size enterprises.
## DSL (lanjutan)

<table>
<thead>
<tr>
<th>Technology</th>
<th>Transmission</th>
<th>No. of Pairs</th>
<th>Maximum Bandwidth</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Upstream</td>
<td>Downstream</td>
</tr>
<tr>
<td>SDSL – Symmetric DSL</td>
<td>Symmetric</td>
<td>1 to 3</td>
<td>2 Mbps</td>
<td>2 Mbps</td>
</tr>
<tr>
<td>HDSL – High Speed DSL</td>
<td>Symmetric</td>
<td>1</td>
<td>2 Mbps</td>
<td>2 Mbps</td>
</tr>
<tr>
<td>ADSL – Asymmetric DSL</td>
<td>Asymmetric</td>
<td>1</td>
<td>640 kbps</td>
<td>8 Mbps</td>
</tr>
<tr>
<td>1st Generation Broadband</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADSL 2 – Asymmetric DSL</td>
<td>Asymmetric</td>
<td>1</td>
<td>640 kbps</td>
<td>12 Mbps</td>
</tr>
<tr>
<td><strong>ADSL 2+ – Asymmetric DSL</strong></td>
<td>Asymmetric</td>
<td>1</td>
<td>1.2 Mbps</td>
<td>25 Mbps</td>
</tr>
<tr>
<td>VDSL – Very High Speed DSL</td>
<td>Symmetric</td>
<td>1</td>
<td>52 Mbps</td>
<td>52 Mbps</td>
</tr>
<tr>
<td>VDSL2</td>
<td>Asymmetric</td>
<td>1</td>
<td>16 Mbps</td>
<td>52 Mbps</td>
</tr>
<tr>
<td></td>
<td>Symmetric</td>
<td>1</td>
<td>100 Mbps</td>
<td>100 Mbps</td>
</tr>
<tr>
<td></td>
<td>Asymmetric</td>
<td>1</td>
<td>16 Mbps</td>
<td>100 Mbps</td>
</tr>
<tr>
<td>2nd Generation Broadband</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Teknik Modulasi pd DSL

- Baseband transmission
  - Pulse amplitude modulation (PAM), misalnya 2B1Q coding.
- Passband transmission
  - Single carrier modulation:
    - Quadrature amplitude modulation (QAM)
    - Carrierless amplitude and phase (CAP)
  - Multicarrier modulation (MCM):
    - Discrete multitone (DMT)
    - Discrete wavelet multitone (DWMT)
Implementasi Konsep DMT

S/P = serial-to-parallel
DAC = digital-to-analog converter
FEC = forward error correction
IFFT = inverse fast Fourier transform
LPF = low pass filter
FFT = fast Fourier transform
P/S = parallel-to-serial

Figure 6.13  Multitone concept implementation: (a) block diagram of a MCM transmitter, (b) basic multicarrier modem, and (c) transmit signal from the DMT modem (Source: [1], reproduced with permission of the IEE).
Spektrum Sinyal ADSL

[Diagram showing the spectrum of ADSL signals with POTS, Upstream, and Downstream bands.]
Fiber Cable Access

Fiber to the x (FTTX) is including:

• fiber-to-the-node (FTTN)
• fiber-to-the-curb (FTTC)
• fiber-to-the-building (FTTB)
• fiber-to-the-home (FTTH)
Teknologi Jaringan Akses

1. *Local loop* pada PSTN
   - Leased Line
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   - ISDN
   - DSL
   - Fiber Cable Access

2. **Cable TV Network**

3. **LAN** (Local Area Network)

4. Wireless Access
Cable TV Network

• Jaringan TV kabel adlh jaringan televisi berbayar yg layanan utamanya menyediakan layanan siaran televisi.
• Dlm perkembangannya kemudian dpt dipakai juga utk akses komunikasi data.
• Medium transmisinya utk distribusi siaran TV ke pelanggan-pelanggan biasanya berupa fiber optik dan kabel coaxial.
• Link satelit dipakai oleh provider utk menerima siaran TV dari stasiun televisi.
• Namun, di lapangan televisi berbayar yg pelanggannya langsung menerima siaran dari satelit terkadang juga disebut TV kabel.
Figure 6.22  Traditional cable TV plant.
Figure 6.23  Cable TV plant modified for cable modem service.
Teknologi Jaringan Akses

1. *Local loop* pada PSTN
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   - DSL
   - Fiber Cable Access

2. Cable TV Network

3. **LAN** (Local Area Network)

4. Wireless Access
Local Area Network (LAN)

- **LANs** provide **high-data-rate communications between computers**, for example, inside one building.
- Because of the high transmission capacity (10 Mbps or higher) only **short distances** are allowed. The typical maximum transmission distance is a few hundred meters.
- **LANs can be interconnected** to make up a wide-area corporate network using switching devices (switches or bridges) or routers.
- The **bridges** or **switches** interconnect separate LAN segments and switch frames from one segment to another with the help of a local hardware address that is stored in the interface unit of each computer.
- **Routers** are devices that use network layer addresses for the routing of packets and they are used to connect LANs to other networks, for example, to the Internet. Routers can also be used to interconnect LANs that use different technologies.
Two Basic Structures of LANs

**Figure 6.25** LAN structure.
LANs Protocols

- Special protocols are standardized to make sure that only one computer transmits at a time.
- The complex standards of LANs specify OSI layer 1, the physical layer, and the so-called medium access sublayer (MAC) of layer 2 (the data link layer).
- The basic task of these protocols is to connect a computer to another via a shared medium as if they were connected by a point-to-point cable.
- The most common LAN is the Ethernet, which has been standardized as ISO 8802-3 or ANSI/IEEE 802-3.
- An Ethernet LAN is logically a bus although its physical structure is often a star where all stations are connected to wiring center called a hub.
LANs Protocols (lanjutan)

- Another common LAN is the *token ring*, developed by IBM, and it is standardized as ISO 8802-5 or IEEE 802-5.
- The typical data rate of this LAN is 16 Mbps.
- In a token ring network, only a computer holding a special short frame called a *token* is able to transmit to the ring.
- Physically the token ring is always built as a *star* although logically it still makes up a ring.
- The token ring has some technical *advantages* over the Ethernet (no collisions, better bandwidth utilization, and deterministic operation) but it is much more complicated because of the token management and thus more expensive.
Multiple-Access Scheme of the Ethernet

- The MAC layer in the Ethernet is defined in ISO 8802-3/IEEE 802.3 and this access method is called **CSMA/CD**.

- **Carrier sense (CS)** means that a workstation senses the channel and does not transmit if it is not free.

- **Multiple access (MA)** means that many workstations share the same channel.

- **Collision detection (CD)** means that each station is capable of detecting a collision that occurs if more than one station transmits at the same time. In the case of a collision, the workstation that detects it immediately stops transmitting and transmits a burst of random data to ensure that all other stations detect the collision as well.
Frame Structure of the Ethernet

**Figure 6.27** Frame structure of the Ethernet (MAC).
Hub untuk Ethernet

Topologi logik: bus (broadcast)
Topologi fisik: star
Switched Ethernet

Figure 6.32  Network extension with and without a switch.
Switching table is updated if the source address in a received frame is unknown or binded to a different port. If no frames from the host are received for a certain period of time, its address is cleared from the table.

**Data link layer address table**

<table>
<thead>
<tr>
<th>MAC address:</th>
<th>Port</th>
</tr>
</thead>
<tbody>
<tr>
<td>080020000001</td>
<td>1</td>
</tr>
<tr>
<td>080020000002</td>
<td>1</td>
</tr>
<tr>
<td>080020000003</td>
<td>1</td>
</tr>
<tr>
<td>080020000008</td>
<td>2</td>
</tr>
<tr>
<td>080020000007</td>
<td>3</td>
</tr>
</tbody>
</table>

**Figure 6.33** Address or switching table of an autolearning switch.
Twisted Pair Cables for Ethernet

Table 6.2
Preferential Order of Ethernet Technologies on Twisted Pair

<table>
<thead>
<tr>
<th>Technology</th>
<th>Mode</th>
<th>Throughput/Connection</th>
<th>Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000BaseTX</td>
<td>Full duplex</td>
<td>2 × 1 Gbps</td>
<td>4p UTP 5</td>
</tr>
<tr>
<td>1000BaseTX</td>
<td>Half duplex</td>
<td>1 Gbps</td>
<td>4p UTP 5</td>
</tr>
<tr>
<td>100BaseTX</td>
<td>Full duplex</td>
<td>2 × 100 Mbps</td>
<td>2p UTP 5/STP</td>
</tr>
<tr>
<td>100BaseT2</td>
<td>Half duplex</td>
<td>100 Mbps</td>
<td>2p UTP 3/4/5</td>
</tr>
<tr>
<td>100BaseT4</td>
<td>Half duplex</td>
<td>100 Mbps</td>
<td>4p UTP 3/4/5</td>
</tr>
<tr>
<td>100BaseTX</td>
<td>Half duplex</td>
<td>100 Mbps</td>
<td>2p UTP 5/STP</td>
</tr>
<tr>
<td>10BaseT</td>
<td>Full duplex</td>
<td>2 × 10 Mbps</td>
<td>2p UTP 3/4/5</td>
</tr>
<tr>
<td>10BaseT</td>
<td>Half duplex</td>
<td>10 Mbps</td>
<td>2p UTP 3/4/5</td>
</tr>
</tbody>
</table>
Ethernet networking

Figure 6.35 Ethernet network operating at 10, 100, and 1,000 Mbps.
Teknologi Jaringan Akses

1. *Local loop* pada PSTN
   - Leased Line
   - Voice-Band Modem
   - ISDN
   - DSL
   - Fiber Cable Access

2. Cable TV Network

3. LAN (Local Area Network)

4. Wireless Access
Wireless Access

Jaringan Akses Nirkabel (Wireless) dpt berupa:

- Radio access network on PLMN (cellular systems)
- Mobile Satellites Communications
- WLL (Wireless Local Loop)
- WLAN (Wireless LAN)
- WiMAX (Worldwide Interoperability for Microwave Access)
Cellular Systems
Mobile Satellites Communications

- Mobile link
- Satellite
- MS
- MSC/VLR
- Gateway
- EIR AUC HLR SUMR
- PSTN
- Public fixed and mobile networks
WLL (Wireless Local Loop)

(a) Overview of a WLL system

(b) Typical WLL system components at the customer premises
# Cellular Systems vs WLL Systems

<table>
<thead>
<tr>
<th>Table 5.1</th>
<th>Comparison of Cellular and WLL Environments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cellular Environment</strong></td>
<td><strong>WLL Environment</strong></td>
</tr>
<tr>
<td>Mobility (subscriber location, hand off, roaming) must be supported</td>
<td>Mobility is not an essential requirement</td>
</tr>
<tr>
<td>Line of sight between the mobile and the base station does not exist</td>
<td>Line of sight can be achieved by suitable base station and antenna spacing</td>
</tr>
<tr>
<td>Poorer quality than wireline service is acceptable</td>
<td>Quality must be equivalent to wireline services</td>
</tr>
</tbody>
</table>
WLAN
(Wireless Local Area Network)

• WLAN berasal dari jaringan komputer berbasis IP (internet protocol).
• Standar WLAN adlh keluarga standar IEEE 802.11, yaitu: IEEE 802.11a, IEEE 802.11b, IEEE 802.11g, IEEE 802.11n, dll.
• Pita frekuensi yg digunakan adlh unlicense frequency band 2.4 GHz dan 5 GHz.
• Disebut jg dgn WiFi (Wireless Fidelity).
WLAN (lanjutan)

<table>
<thead>
<tr>
<th>Spesifikasi</th>
<th>Kecepatan</th>
<th>Frekuensi Band</th>
<th>Cocok dengan</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.11b</td>
<td>11 Mb/s</td>
<td>~2.4 GHz</td>
<td>b</td>
</tr>
<tr>
<td>802.11a</td>
<td>54 Mb/s</td>
<td>~5 GHz</td>
<td>a</td>
</tr>
<tr>
<td>802.11g</td>
<td>54 Mb/s</td>
<td>~2.4 GHz</td>
<td>b, g</td>
</tr>
<tr>
<td>802.11n</td>
<td>100 Mb/s</td>
<td>~2.4 GHz</td>
<td>b, g, n</td>
</tr>
</tbody>
</table>
WiMAX
(Worldwide Interoperability for Microwave Access)

• WiMAX adlh istilah utk jaringan berbasis Standar IEEE 802.16
• Disebut jg Broadband Wireless Access (BWA)
• Dikategorikan ke dlm MAN (metropolitan area network)
• Standar IEEE 802.16d → Fixed WiMAX (3G)
• Standar IEEE 802.16e → Mobile WiMAX (3.9G)
• Standar IEEE 802.16m → WiMAX-2 (4G)
## Perbandingan Teknologi Wireless

<table>
<thead>
<tr>
<th></th>
<th>WiFi 802.11g</th>
<th>WiMAX 802.16-2004*</th>
<th>WiMAX 802.16e</th>
<th>CDMA2000 1x EV-DO</th>
<th>WCDMA/UMTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approximate max reach (dependent on many factors)</td>
<td>100 Meters 8 Km</td>
<td>8 Km</td>
<td>5 Km</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Maximum throughput</td>
<td>54 Mbps</td>
<td>75 Mbps (20 MHz band)</td>
<td>30 Mbps (10 MHz band)</td>
<td>3.1 Mbps (EVDO Rev. A)</td>
<td>2 Mbps (10+ Mbps for HSDPA)</td>
</tr>
<tr>
<td>Typical Frequency bands</td>
<td>2.4 GHz</td>
<td>2–11 GHz</td>
<td>2–6 GHz</td>
<td>1900 MHz</td>
<td>1800, 1900, 2100 MHz</td>
</tr>
<tr>
<td>Application</td>
<td>Wireless LAN</td>
<td>Fixed Wireless Broadband (eg-DSL alternative)</td>
<td>Portable Wireless Broadband</td>
<td>Mobile Wireless Broadband</td>
<td>Mobile Wireless Broadband</td>
</tr>
</tbody>
</table>
## Table 1.2 Comparison of WiMAX with Other Broadband Wireless Technologies

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Fixed WiMAX</th>
<th>Mobile WiMAX</th>
<th>HSPA</th>
<th>1x EV-DO Rev A</th>
<th>Wi-Fi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standards</td>
<td>IEEE 802.16-2004</td>
<td>IEEE 802.16e-2005</td>
<td>3GPP Release 6</td>
<td>3GPP2</td>
<td>IEEE 802.11a/g/n</td>
</tr>
<tr>
<td>Peak down link data rate</td>
<td>9.4Mbps in 3.5MHz with 3:1 DL-to-UL ratio TDD; 6.1Mbps with 1:1</td>
<td>46Mbps&lt;sup&gt;a&lt;/sup&gt; with 3:1 DL- to-UL ratio TDD; 32Mbps with 1:1</td>
<td>14.4Mbps using all 15 codes; 7.2Mbps with 10 codes</td>
<td>3.1Mbps; Rev. B will support 4.9Mbps</td>
<td>54 Mbps&lt;sup&gt;b&lt;/sup&gt; shared using 802.11a/g; more than 100Mbps peak layer 2 throughput using 802.11n</td>
</tr>
<tr>
<td>Peak uplink data rate</td>
<td>3.3Mbps in 3.5MHz using 3:1 DL-to-UL ratio; 6.5Mbps with 1:1</td>
<td>7Mbps in 10MHz using 3:1 DL-to-UL ratio; 4Mbps using 1:1</td>
<td>1.4Mbps initially; 5.8Mbps later</td>
<td>1.8Mbps</td>
<td></td>
</tr>
<tr>
<td>Bandwidth</td>
<td>3.5MHz and 7MHz in 3.5GHz band; 10MHz in 5.8GHz band</td>
<td>3.5MHz, 7MHz, 5MHz, 10MHz, and 8.75MHz initially</td>
<td>5MHz</td>
<td>1.25MHz</td>
<td>20MHz for 802.11a/g; 20/40MHz for 802.11n</td>
</tr>
</tbody>
</table>
### Lanjutan:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Fixed WiMAX</th>
<th>Mobile WiMAX</th>
<th>HSPA</th>
<th>1x EV-DO Rev A</th>
<th>Wi-Fi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulation</td>
<td>QPSK, 16 QAM, 64 QAM</td>
<td>QPSK, 16 QAM, 64 QAM</td>
<td>QPSK, 16 QAM</td>
<td>QPSK, 8 PSK, 16 QAM, 64 QAM</td>
<td>BPSK, QPSK, 16 QAM, 64 QAM</td>
</tr>
<tr>
<td>Multiplexing</td>
<td>TDM</td>
<td>TDM/OFDMA</td>
<td>TDM/CDMA</td>
<td>TDM/CDMA</td>
<td>CSMA</td>
</tr>
<tr>
<td>Duplexing</td>
<td>TDD, FDD</td>
<td>TDD initially</td>
<td>FDD</td>
<td>FDD</td>
<td>TDD</td>
</tr>
<tr>
<td>Frequency</td>
<td>3.5GHz and 5.8GHz initially</td>
<td>2.3GHz, 2.5GHz, 1,900/1,800/2,100MHz</td>
<td>800/900/1,800/1,900/1,900MHz</td>
<td>800/900/1,800/1,900MHz</td>
<td>2.4GHz, 5GHz</td>
</tr>
<tr>
<td>Coverage (typical)</td>
<td>3–5 miles</td>
<td>&lt; 2 miles</td>
<td>1–3 miles</td>
<td>1–3 miles</td>
<td>&lt; 100 ft indoors; &lt; 1000 ft outdoors</td>
</tr>
</tbody>
</table>

- a. Assumes 2 × 2 MIMO and a 10MHz channel.
- b. Due to inefficient CSMA MAC, this typically translates to only ~20Mbps to 25Mbps layer 2 throughput.
1. Jelaskan perbedaan antara jaringan akses dan jaringan transport! Serta berikan contoh, masing-masing minimal tiga contoh!

2. Uraikan perkembangan teknologi jaringan akses pada *local loop* PSTN!

3. Jelaskan perbedaan antara LAN Ethernet dan LAN Token Ring!

4. Berikan empat contoh jaringan akses nirkabel (*wireless access*) dan jelaskan perbedaan antar keempat jaringan tersebut!
Sekian, terima kasih, semoga berkah.

Ada pertanyaan?