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8

Distributed Systems

Uwe R. Zimmer - The Australian National University



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OSI network reference model

Standardized as the

Open Systems Interconnection (OSI) reference model by the
International Standardization Organization (ISO) in 1977

- 7 layer architecture
- Connection oriented

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Hardy implemented anywhere in full ...

...but its **concepts and terminology** are *widely used*,
when describing existing and designing new protocols ...

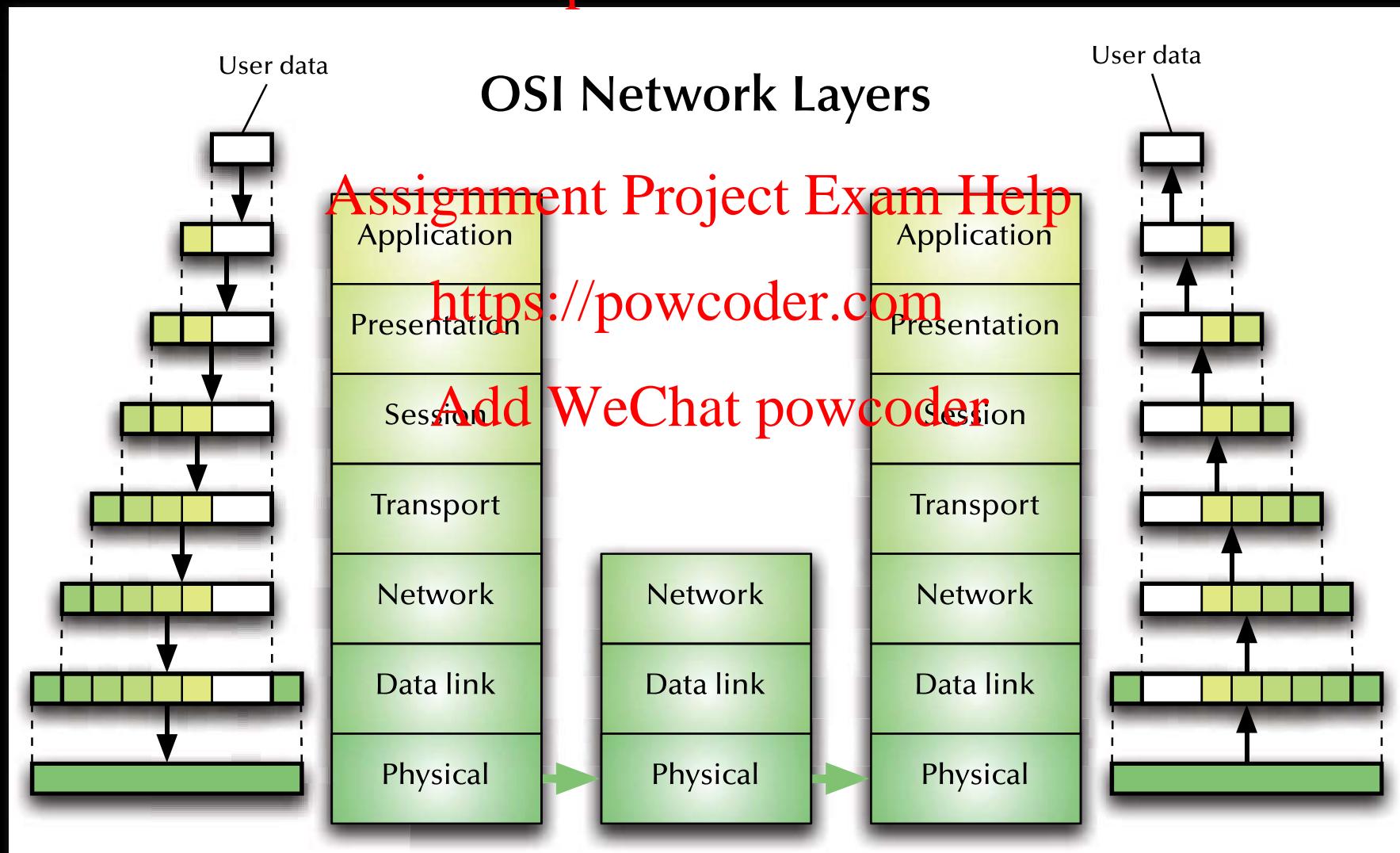


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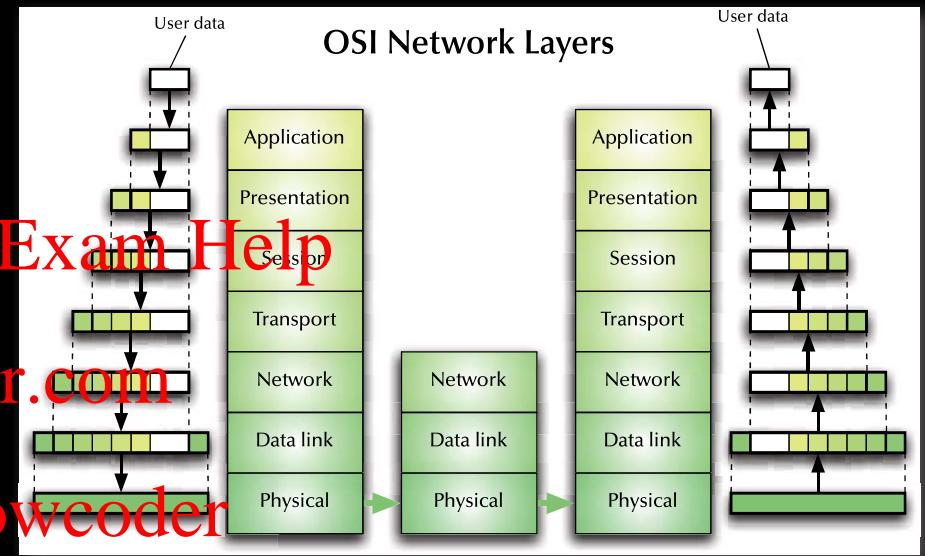
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1: Physical Layer

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- *Service:* Transmission of a raw bit stream over a communication channel
- *Functions:* Conversion of bits into electrical or optical signals
- *Examples:* X.21, Ethernet (cable, detectors & amplifiers)



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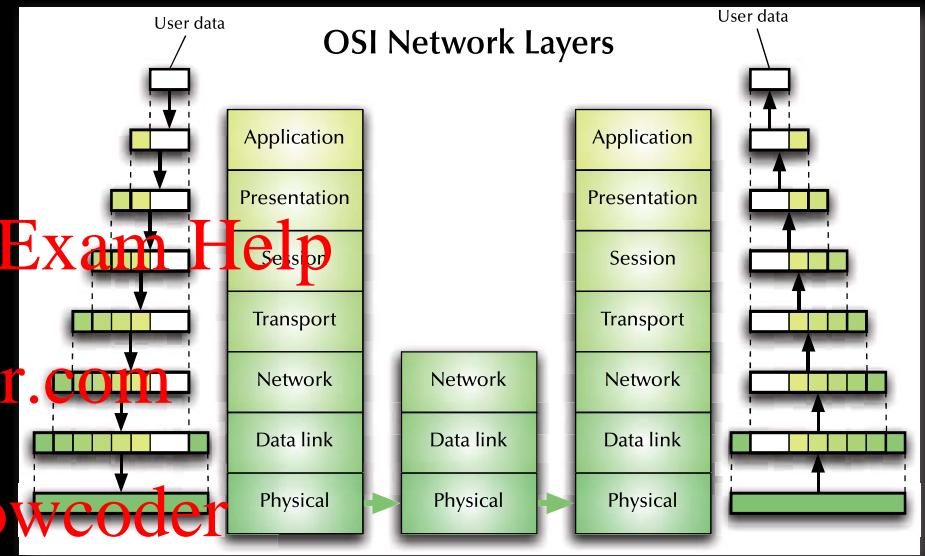
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2: Data Link Layer

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- *Service:* Reliable transfer of frames over a link
- *Functions:* Synchronization, error correction, flow control
- *Examples:* HDLC (high level data link control protocol), LAP-B (link access procedure, balanced), LAP-D (link access procedure, D-channel), LLC (link level control), ...



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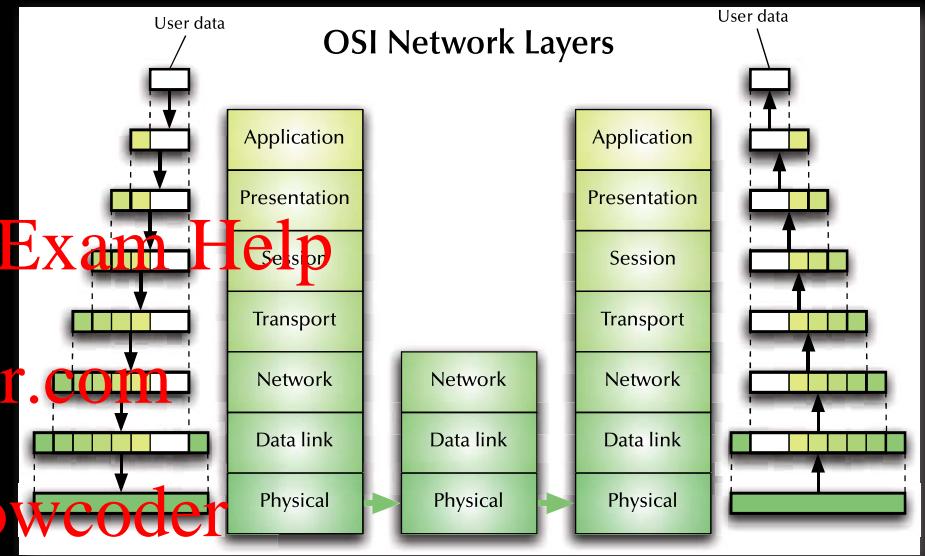
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3: Network Layer

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- *Service:* Transfer of packets inside the network
- *Functions:* Routing, addressing, switching, congestion control
- *Examples:* IP, X.25



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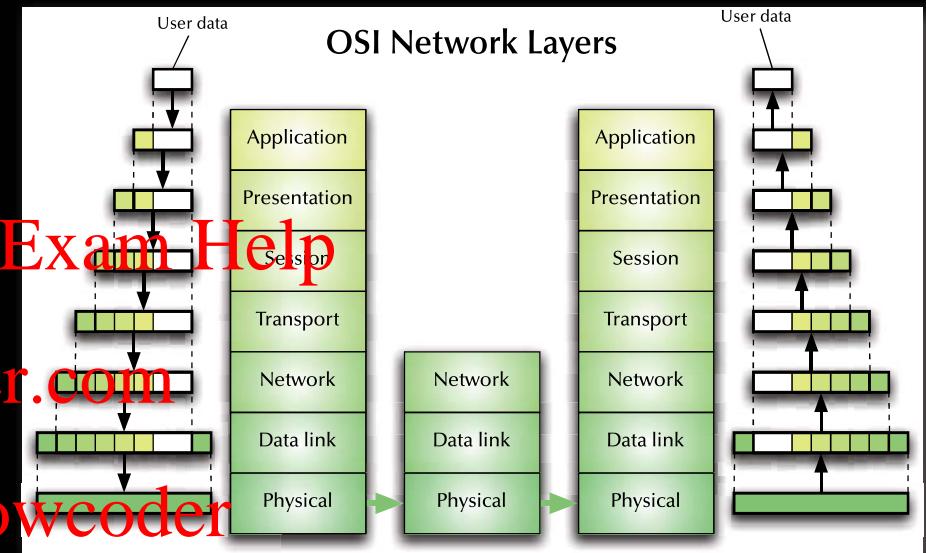
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4: Transport Layer

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- *Service:* Transfer of data between hosts
- *Functions:* Connection establishment, management, termination, flow-control, multiplexing, error detection
- *Examples:* TCP, UDP, ISO TP0-TP4



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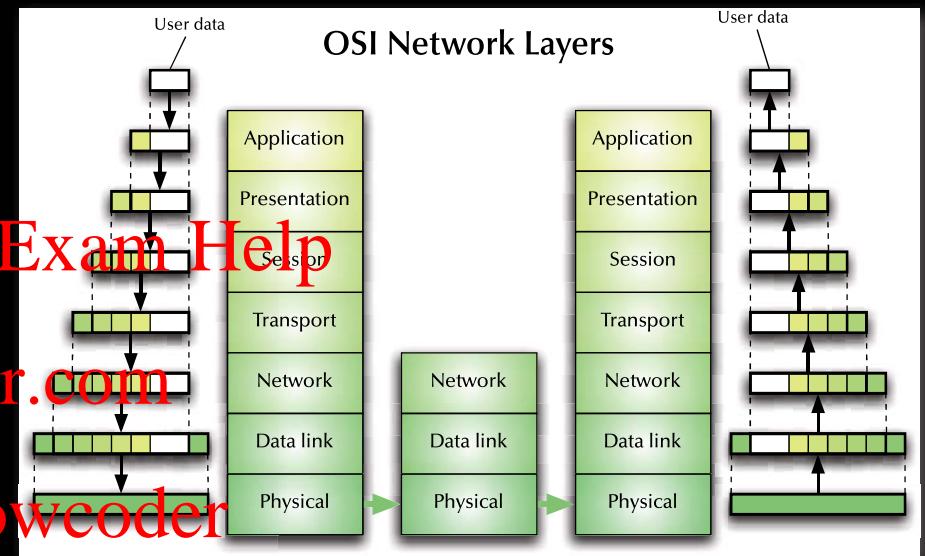
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5: Session Layer

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- *Service:* Coordination of the dialogue between application programs
- *Functions:* Session establishment, management, termination
- *Examples:* RPC



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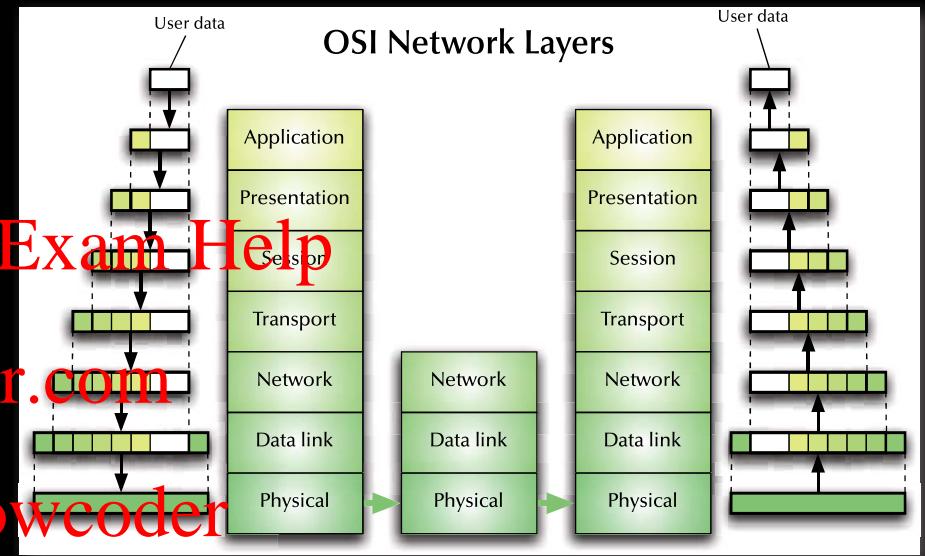
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6: Presentation Layer

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- *Service:* Provision of platform independent coding and encryption
- *Functions:* Code conversion, encryption, virtual devices
- *Examples:* ISO code conversion, PGP encryption



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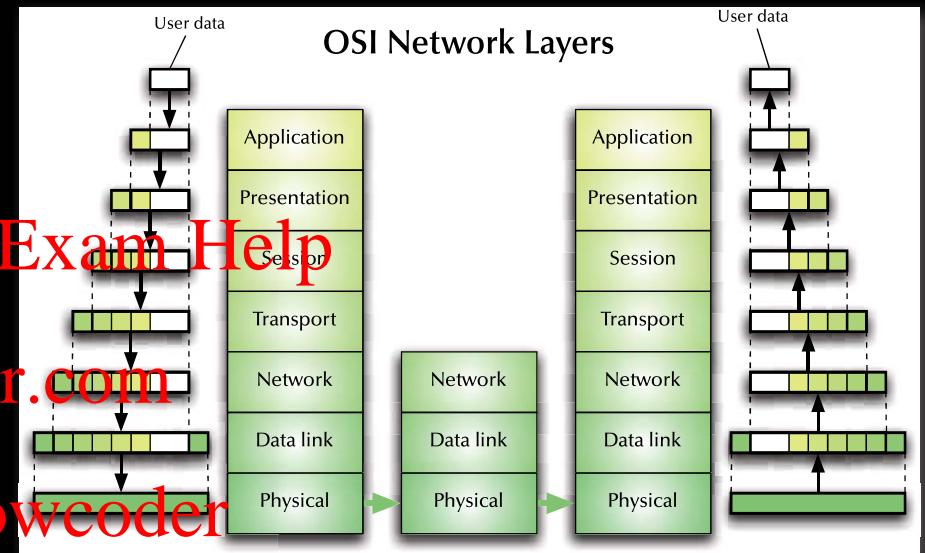
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7: Application Layer

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- *Service:* Network access for application programs
- *Functions:* Application/OS specific
- *Examples:* APIs for mail, ftp, ssh, scp, discovery protocols ...



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Serial Peripheral Interface (SPI)

- ☞ Used by gazillions of devices . . . and it's not even a formal standard!
- ☞ Speed only limited by what both sides can survive
- ☞ Usually push-pull drivers, i.e. fast and reliable, yet not friendly to wrong wiring/programming.



1.8" COLOR TFT LCD display from Adafruit



SanDisk marketing photo



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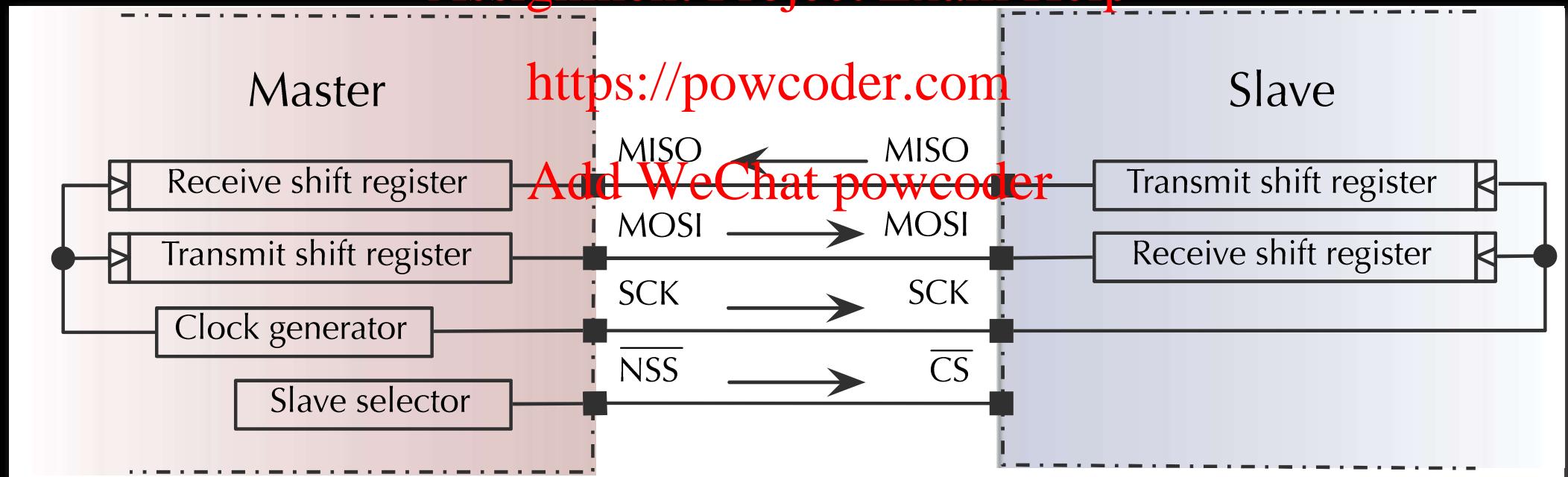
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Serial Peripheral Interface (SPI)

Full Duplex, 4-wire, flexible clock rate
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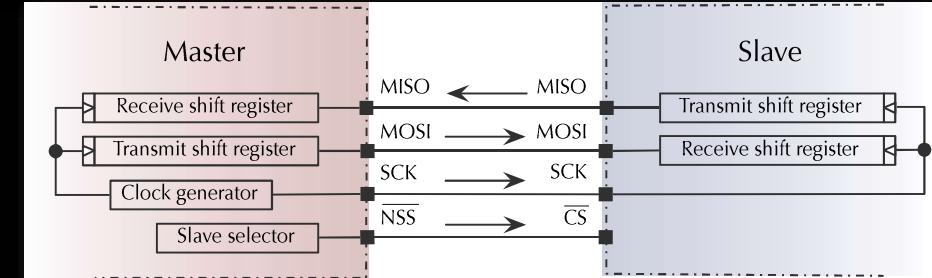
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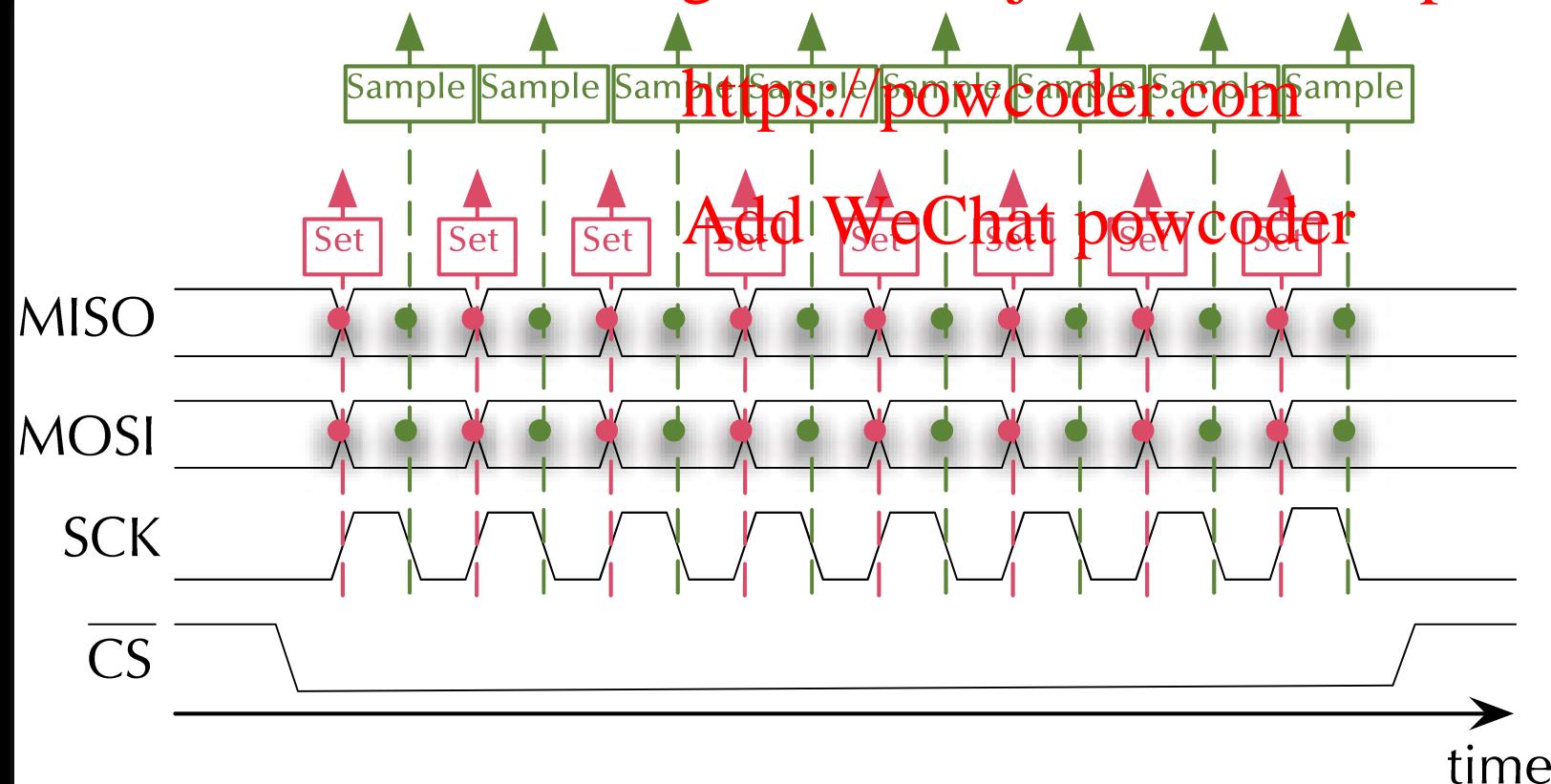
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Serial Peripheral Interface (SPI)



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Clock phase and polarity need to be agreed upon



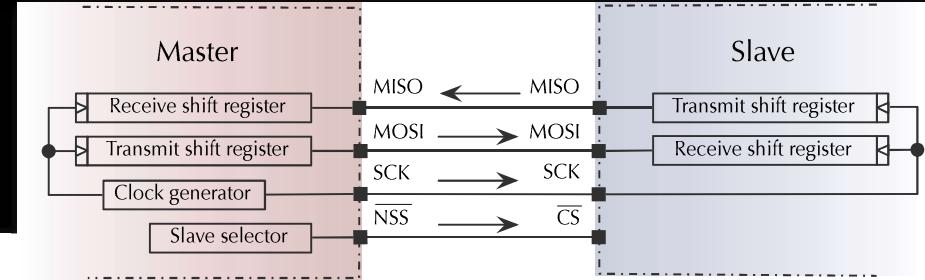
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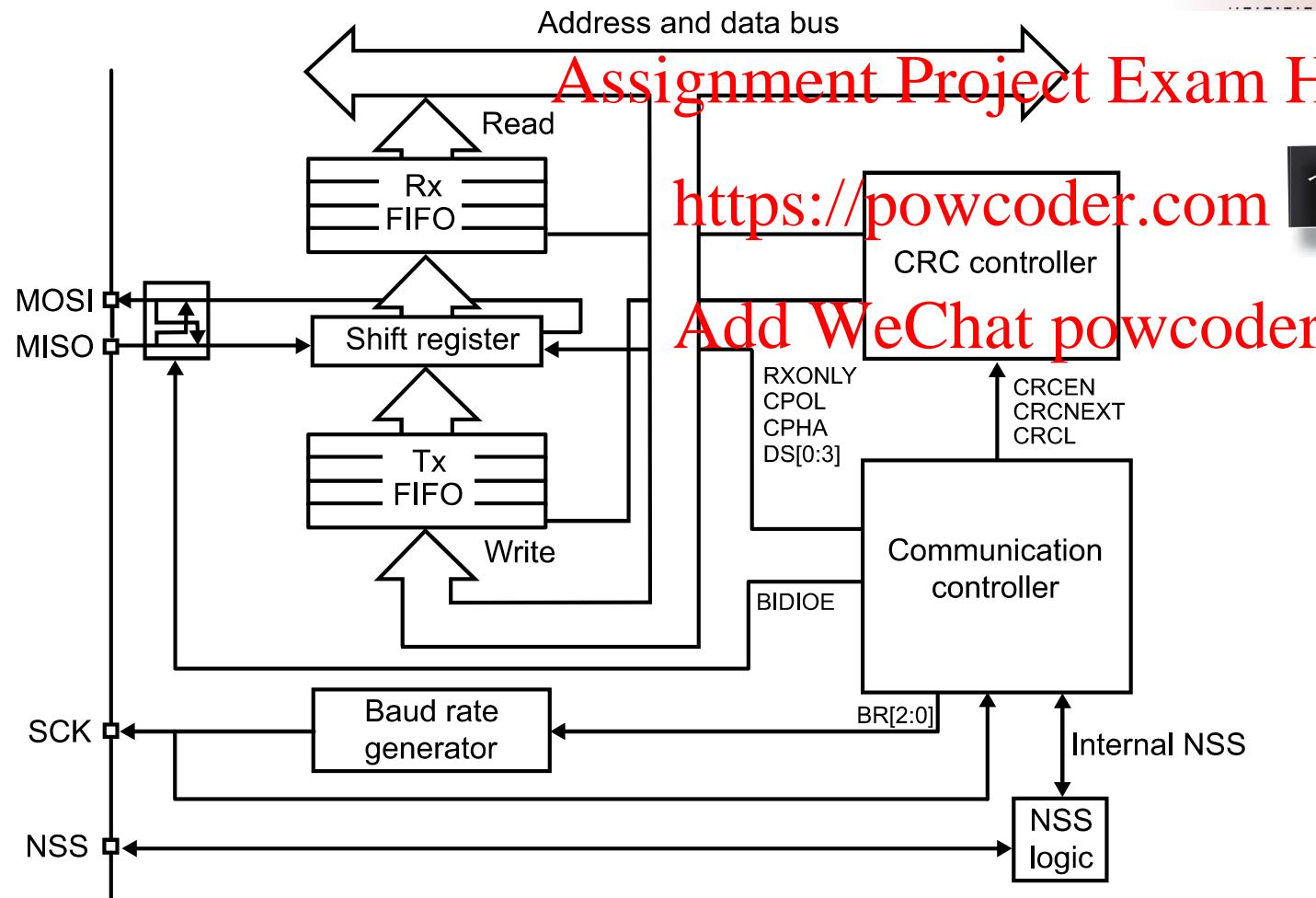
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Serial Peripheral Interface (SPI)



Address and data bus
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1 shift register?

CRC?

FIFOs?

Data connected to an internal bus?

DMA?

Speed?

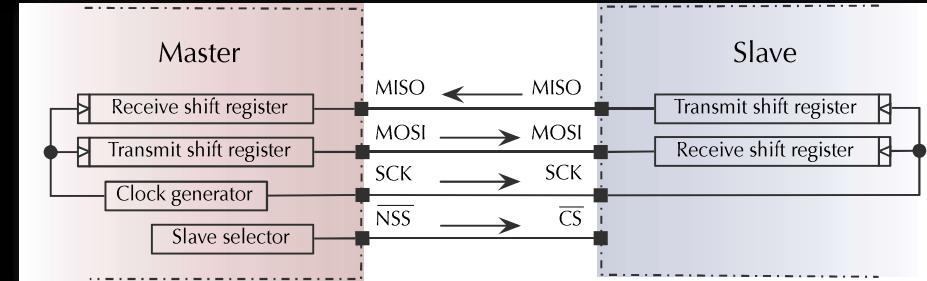
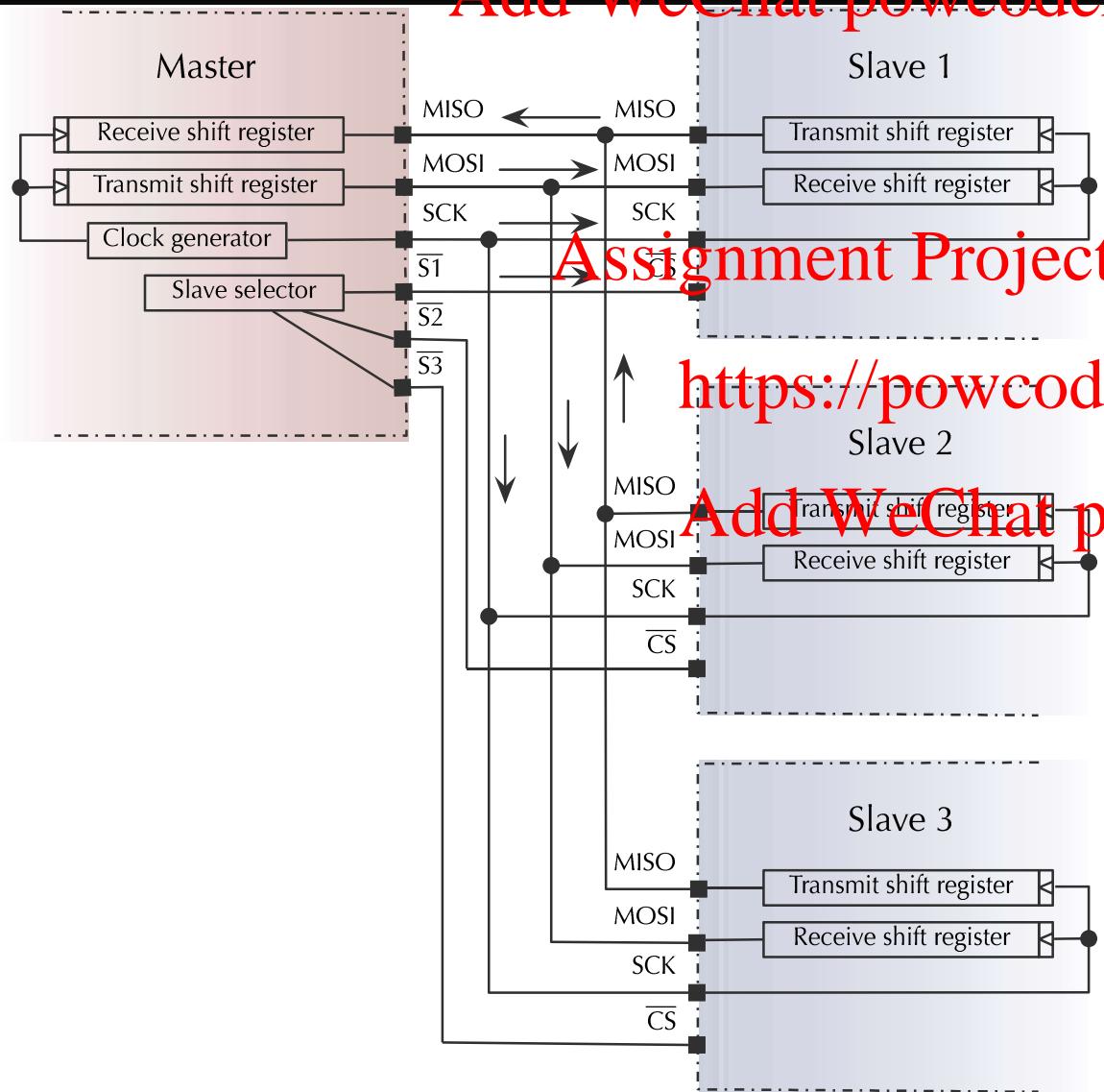


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Full duplex with 1
out of x slaves



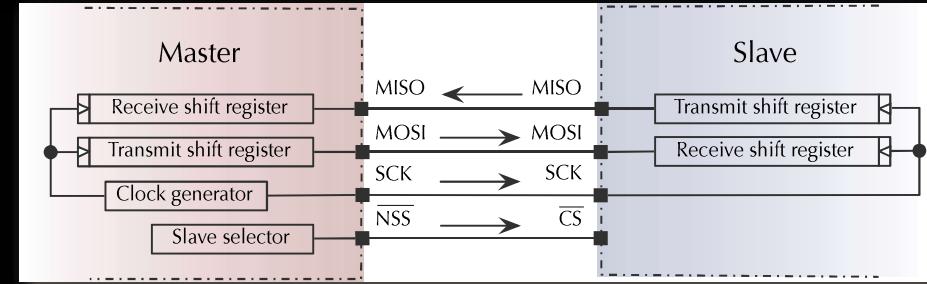
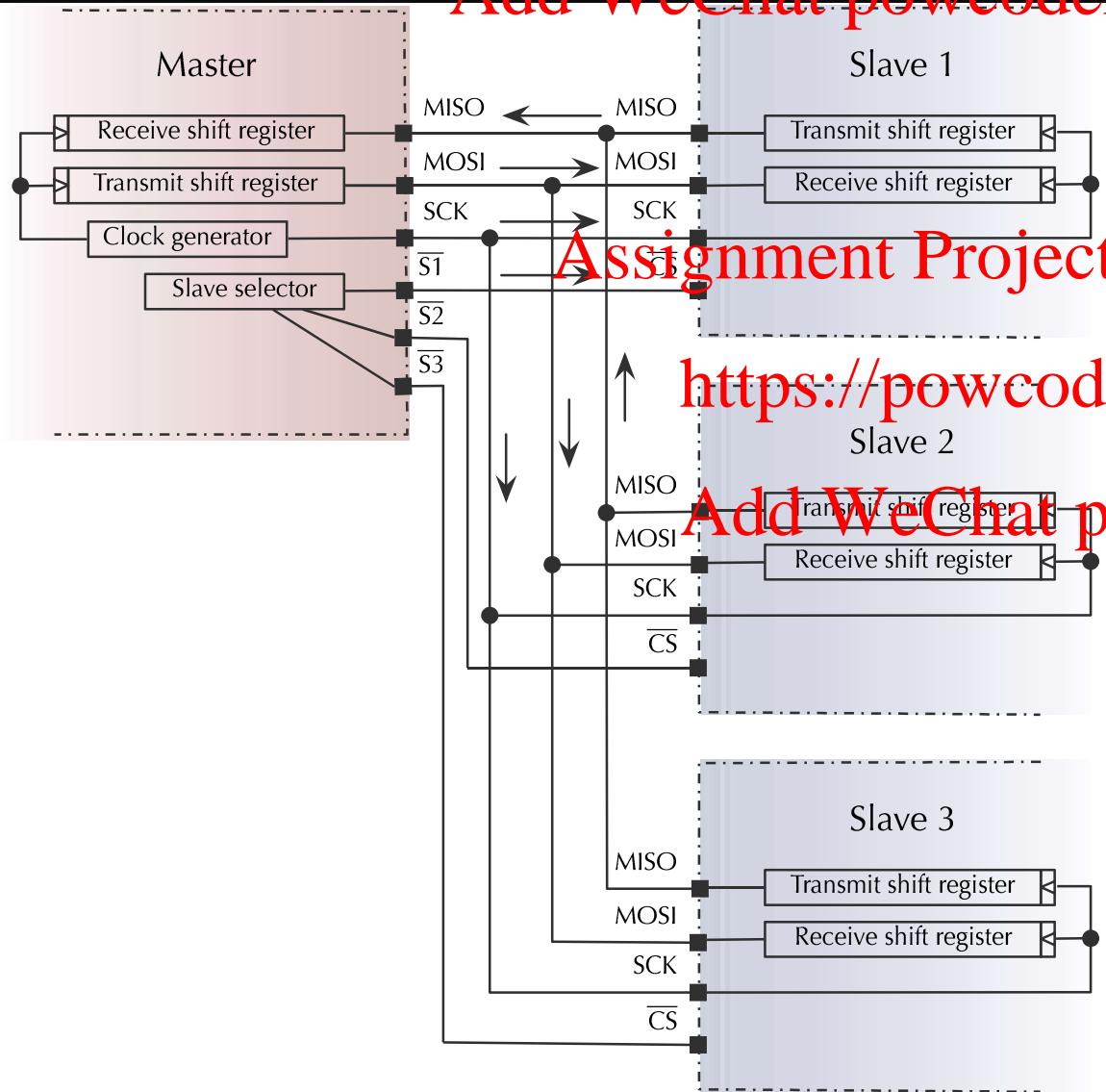
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Concurrent simplex
with y out of x slaves



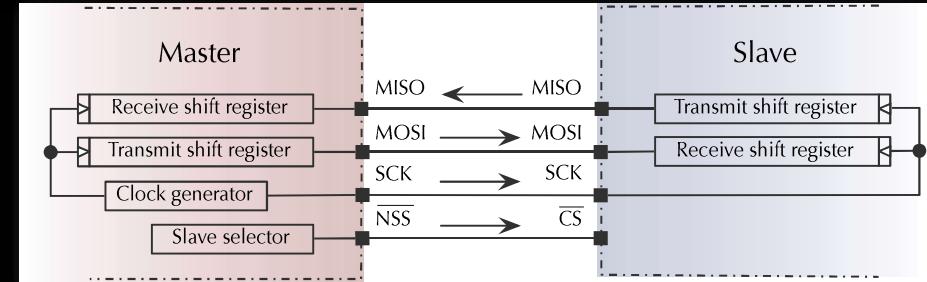
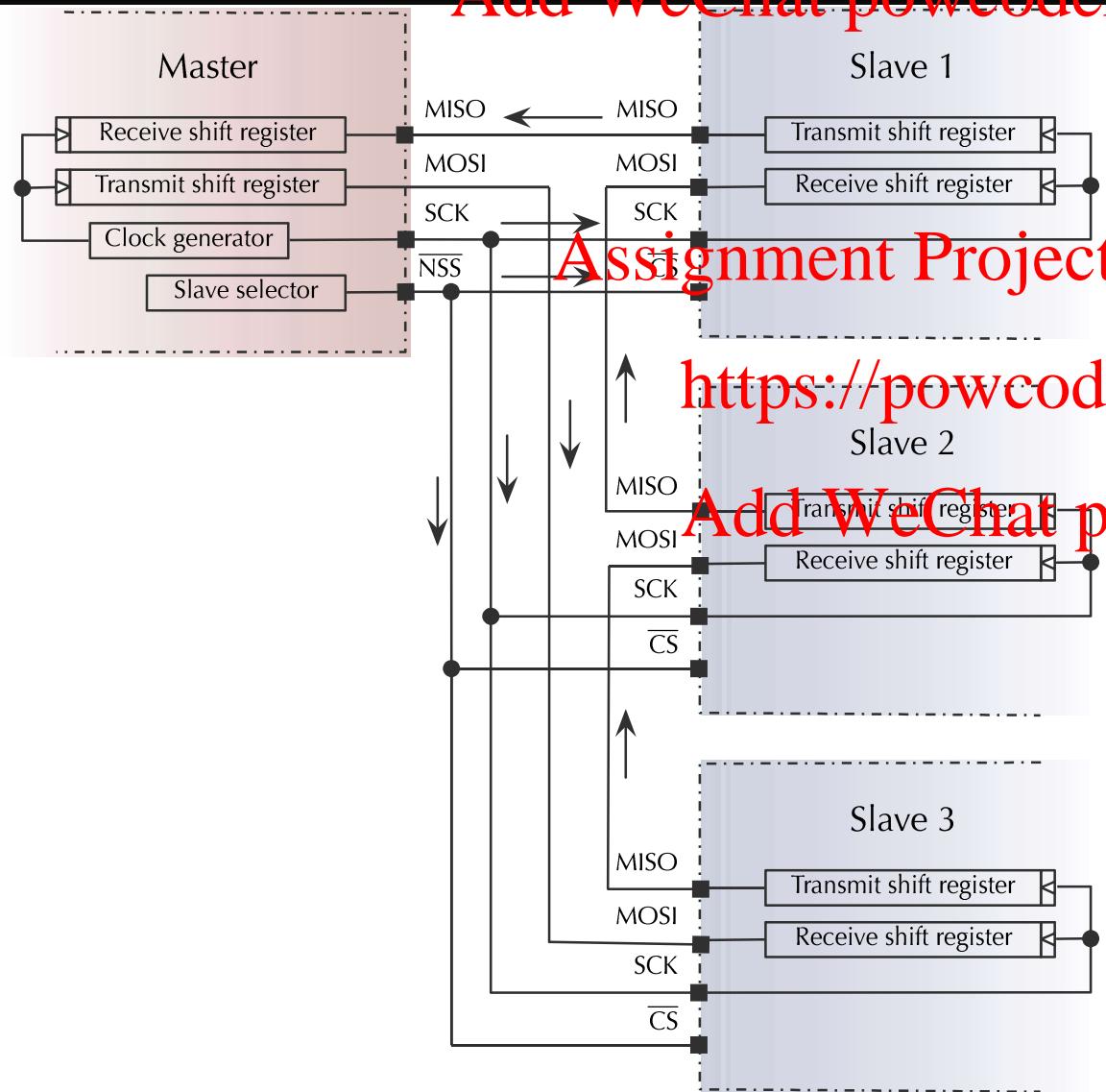
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Concurrent
daisy chaining
with all slaves

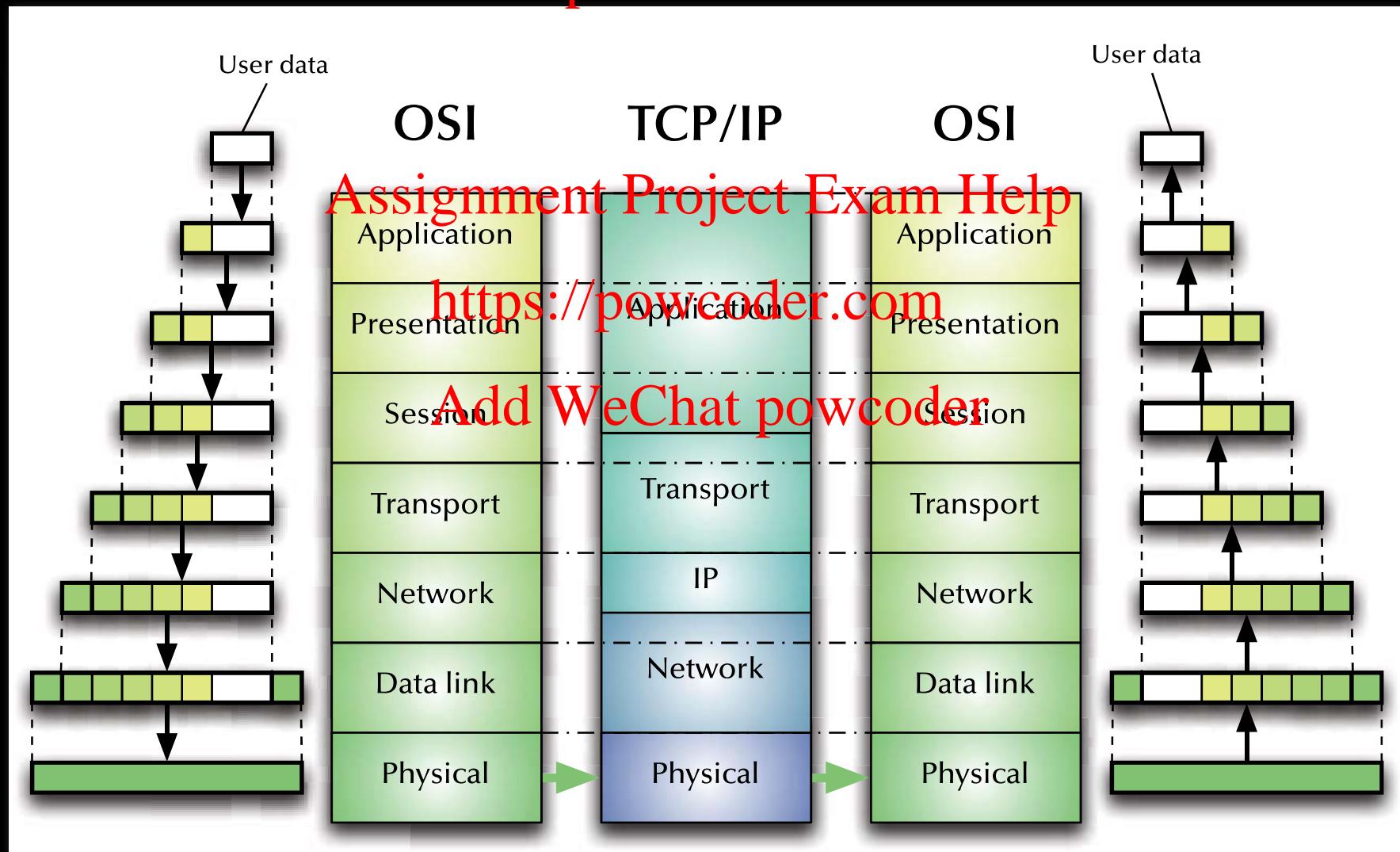


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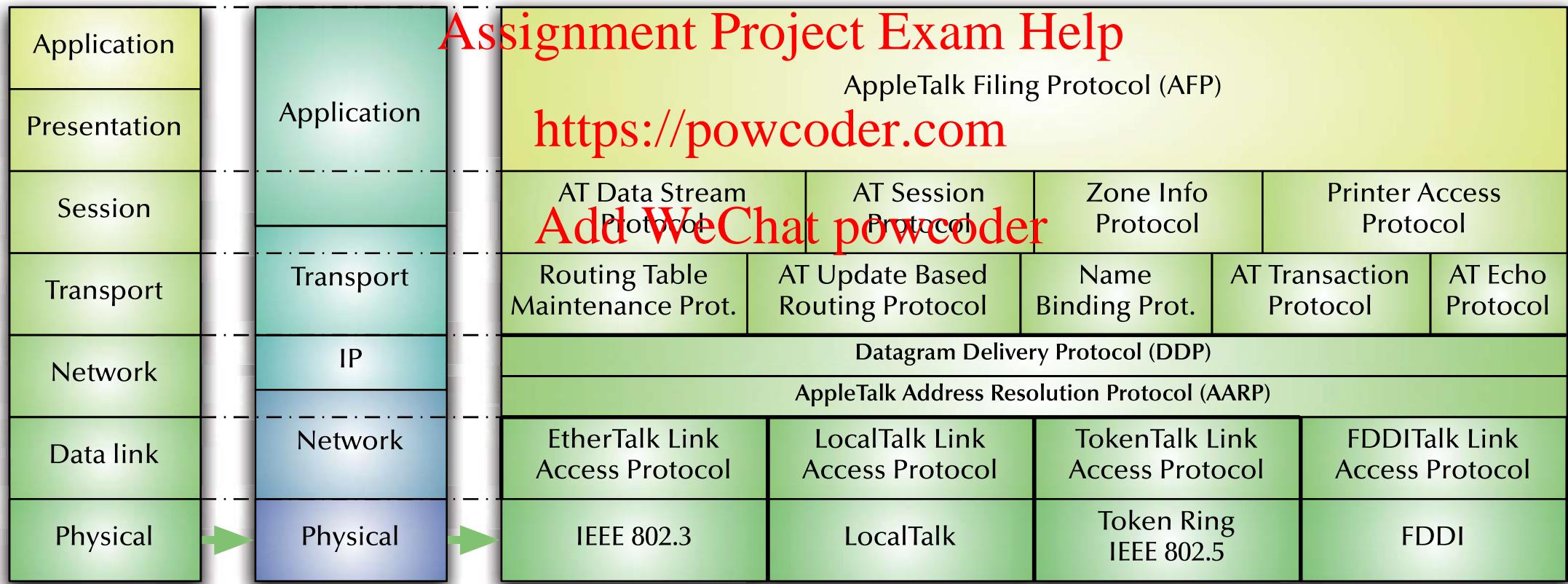
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OSI

TCP/IP

AppleTalk





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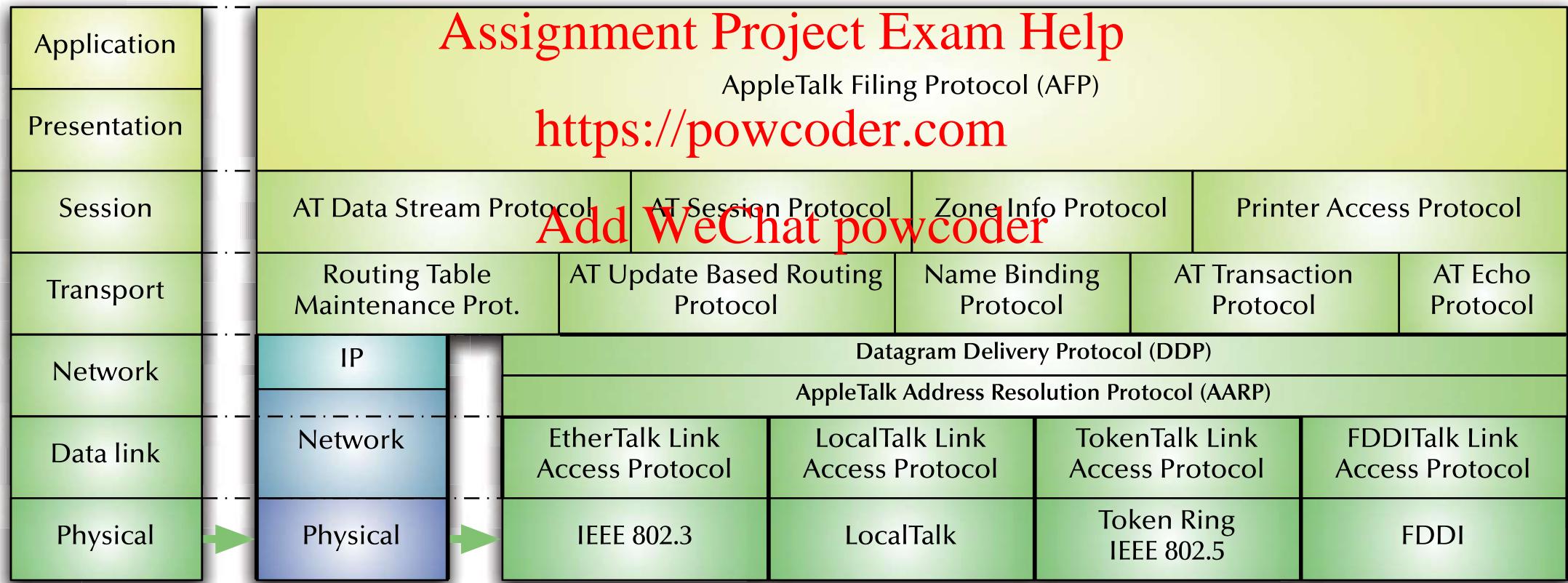
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OSI

AppleTalk over IP





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Ethernet / IEEE 802.3

Local area network (LAN) developed by Xerox in the 70's

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- 10 Mbps specification 1.0 by DEC, Intel, & Xerox in 1980.
- First standard as IEEE 802.3 in 1983 (10 Mbps over thick co-ax cables).
- currently 1 Gbps (802.3ab) copper cable ports used in most desktops and laptops.
- currently standards up to 100 Gbps (IEEE 802.3ba 2010).
- more than 85 % of current LAN lines worldwide
(according to the International Data Corporation (IDC)).

☞ Carrier Sense Multiple Access with Collision Detection (CSMA/CD)



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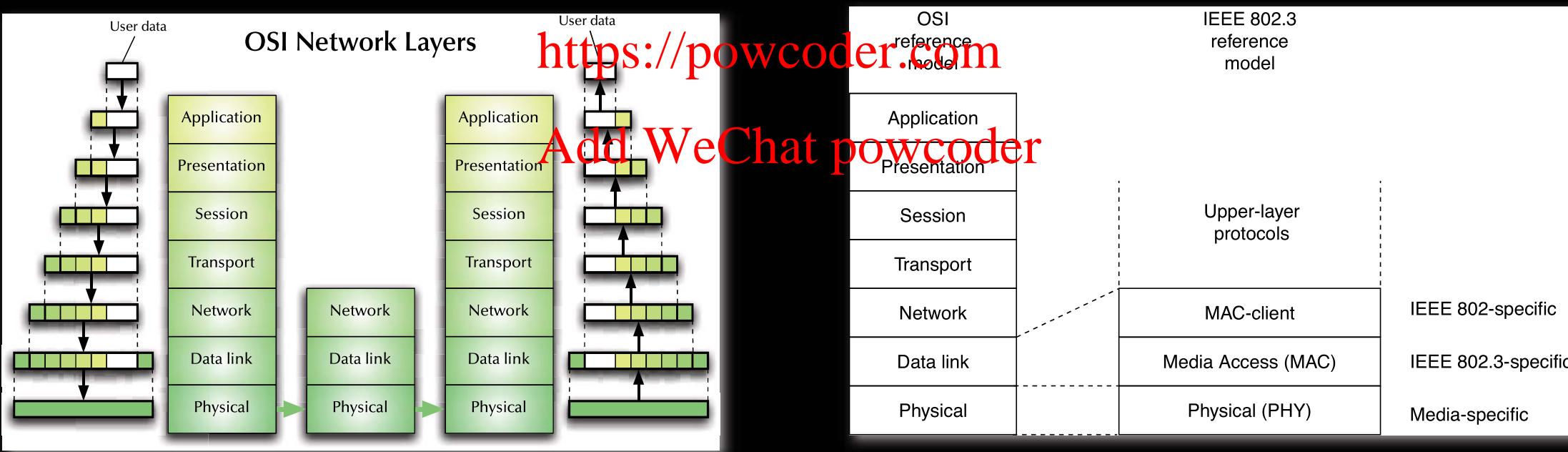
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Ethernet / IEEE 802.3

OSI relation: PHY, MAC, MAC-client

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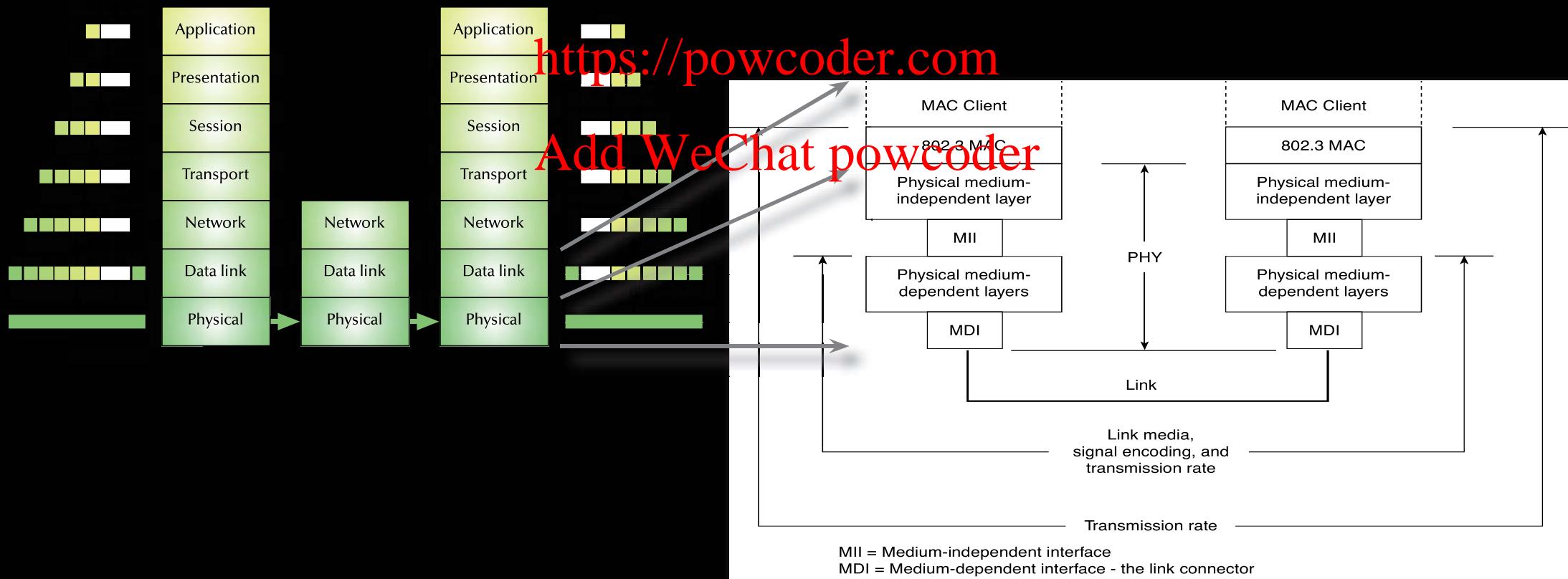
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OSI relation: PHY, MAC, MAC-client

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Ethernet / IEEE 802.11

Wireless local area network (WLAN) developed in the 90's
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- First standard as IEEE 802.11 in 1997 (1-2 Mbps over 2.4 GHz).
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- Typical usage at 54 Mbps over 2.4 GHz carrier at 20 MHz bandwidth.
- Current standards up to 780 Mbps (802.11ac), over 5 GHz carrier at 160 MHz bandwidth.
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- Future standards are designed for up to 100 Gbps over 60 GHz carrier.
- Direct relation to IEEE 802.3 and similar OSI layer association.

☞ **Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)**

☞ **Direct-Sequence Spread Spectrum (DSSS)**



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Bluetooth

Wireless local area network (WLAN) developed in the 90's with different features than 802.11:

- Lower power consumption.
- Shorter ranges.
- Lower data rates (typically < 1 Mbps).
- Ad-hoc networking (no infrastructure required).

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☞ Combinations of 802.11 and Bluetooth OSI layers are possible to achieve the required features set.



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Token Ring / IEEE 802.5 /

Fibre Distributed Data Interface (FDDI)

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- “Token Ring” developed by IBM in the 70’s
- IEEE 802.5 standard is modelled after the IBM Token Ring architecture (specifications are slightly different, but basically compatible)
- IBM Token Ring requests are star topology as well as twisted pair cables, while IEEE 802.5 is unspecified in topology and medium
- Fibre Distributed Data Interface combines a token ring architecture with a dual-ring, fibre-optical, physical network.

☞ Unlike CSMA/CD, **Token ring is deterministic**
(with respect to its timing behaviour)

☞ **FDDI is deterministic and failure resistant**

☞ None of the above is currently used in performance oriented applications.



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Fibre Channel

- Developed in the late 80's.
- ANSI standard since 1994.

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- Current standards allow for 16 Gbps per link.

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- Allows for three different topologies:

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☞ **Point-to-point:** 2 addresses

☞ **Arbitrated loop** (similar to token ring): 127 addresses ☞ deterministic, real-time capable

☞ **Switched fabric:** 2^{24} addresses, many topologies and concurrent data links possible

- Defines OSI equivalent layers up to the session level.

☞ Mostly used in storage arrays,
but applicable to super-computers and high integrity systems as well.



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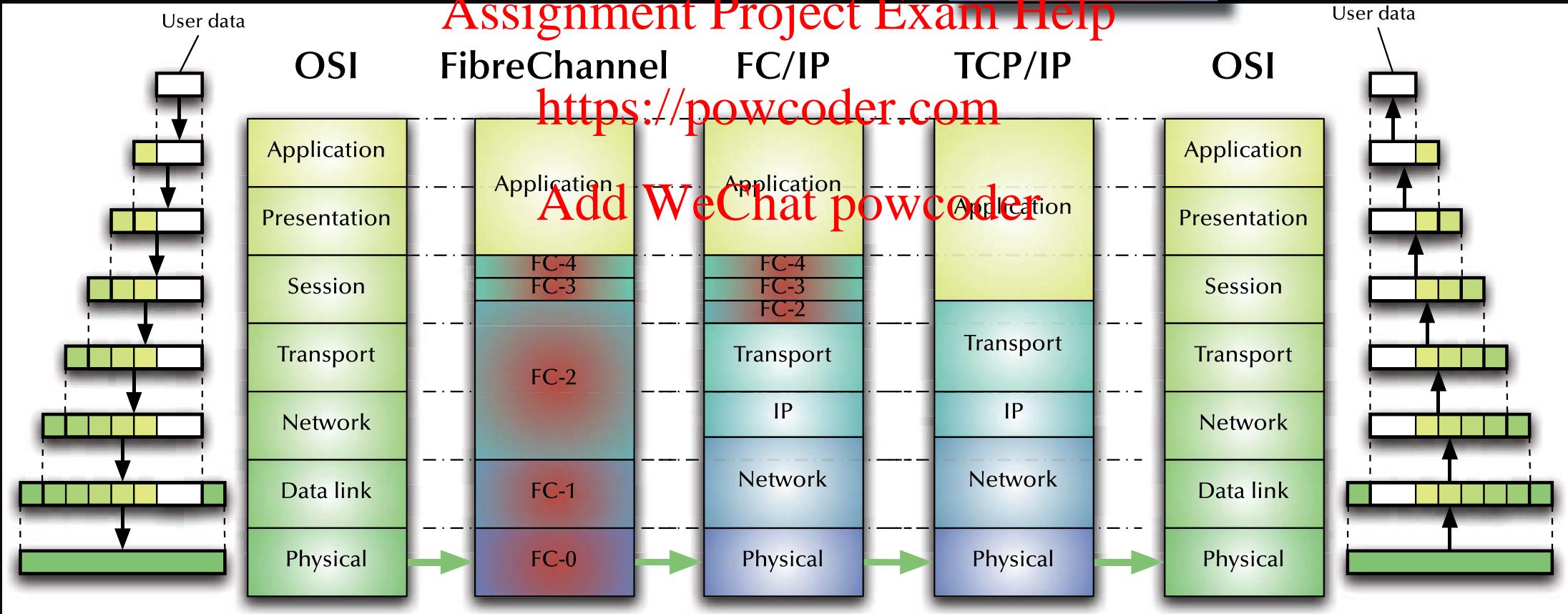
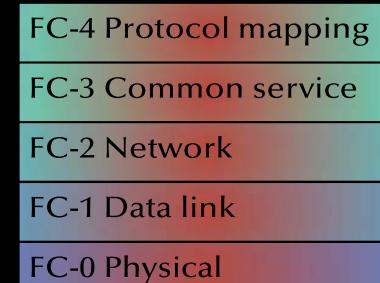
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Fibre Channel

Mapping of Fibre Channel to OSI layers:





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InfiniBand

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- Developed in the late 90's
 - Defined by the InfiniBand Trade Association (IBTA) since 1999.
 - Current standards allow for 25 Gbps per link.
 - Switched fabric topologies. Add WeChat powcoder
 - Concurrent data links possible (commonly up to 12 ☰ 300 Gbps).
 - Defines only the *data-link layer* and parts of the *network layer*.
 - Existing devices use copper cables (instead of optical fibres).
- ☞ Mostly used in super-computers and clusters but applicable to storage arrays as well.
- ☞ Cheaper than Ethernet or FibreChannel at high data-rates.
- ☞ Small packets (only up to 4 kB) and no session control.