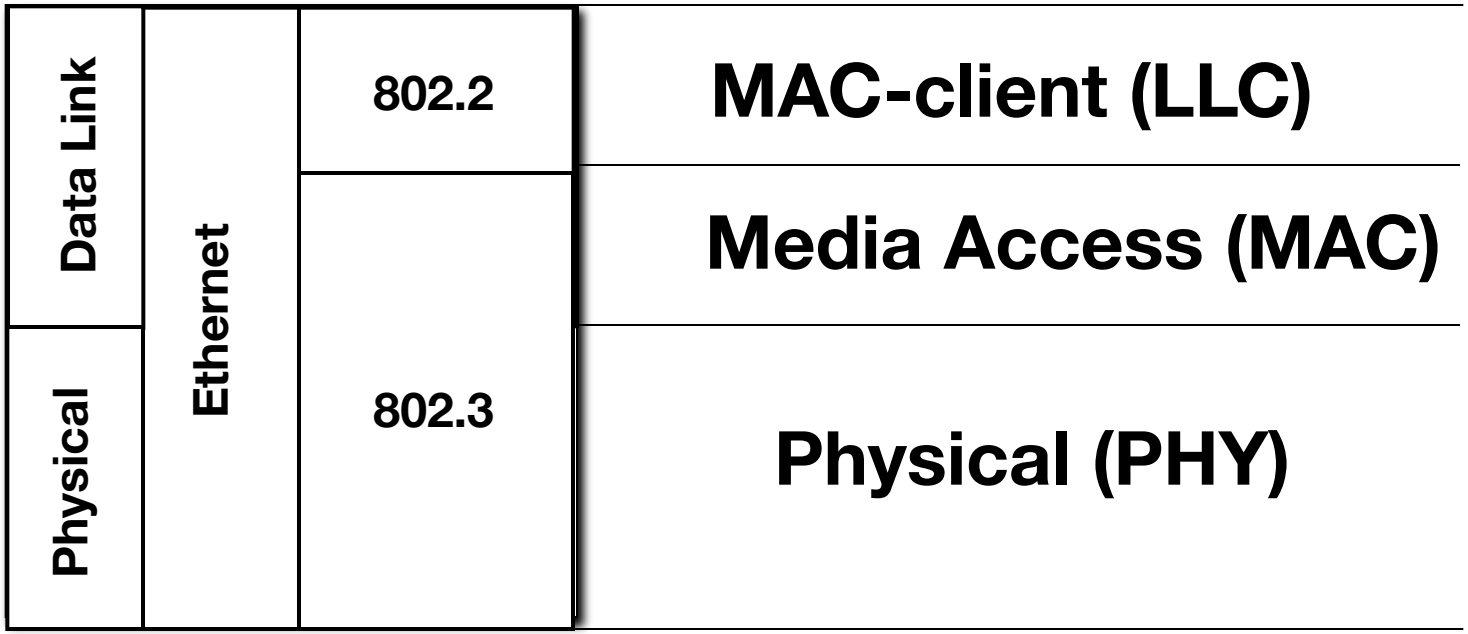
Технология Ethernet для сетей доступа и транспорта

Профессор В.Ю. Деарт

Содержание

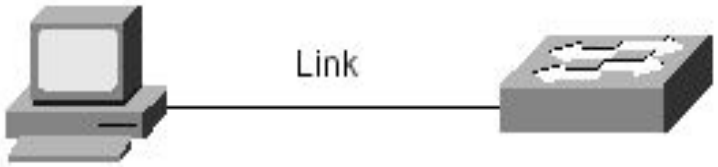
- 1. Технология Ethernet
- 2. Виртуальные локальные сети VLAN
- 3. Технология Carrier Ethernet для транспортных сетей
- 4. Принципы построения Metro Ethernet

Технология *Ethernet:* уровни *BRM OSI*

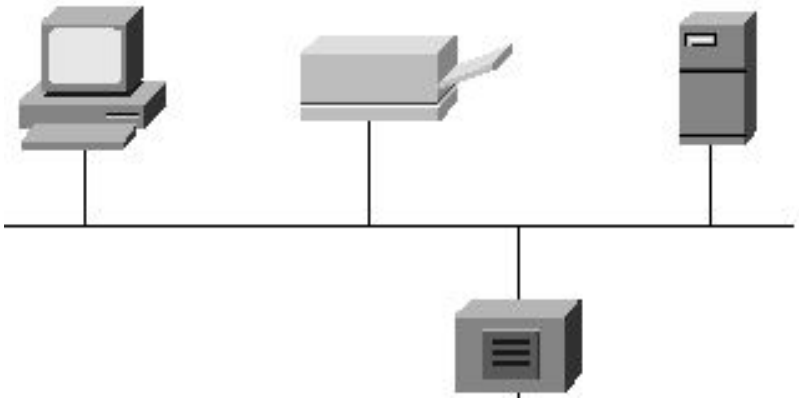


Топологии соединений и сетей

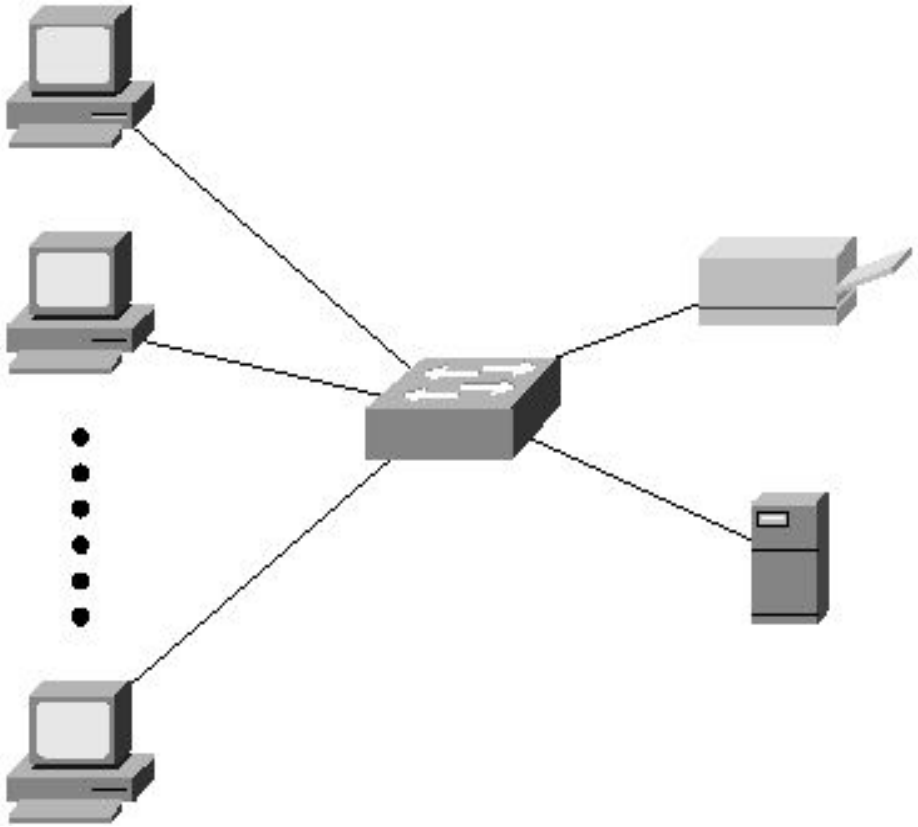
Ethernet



Point-to-Poin
t
Structure



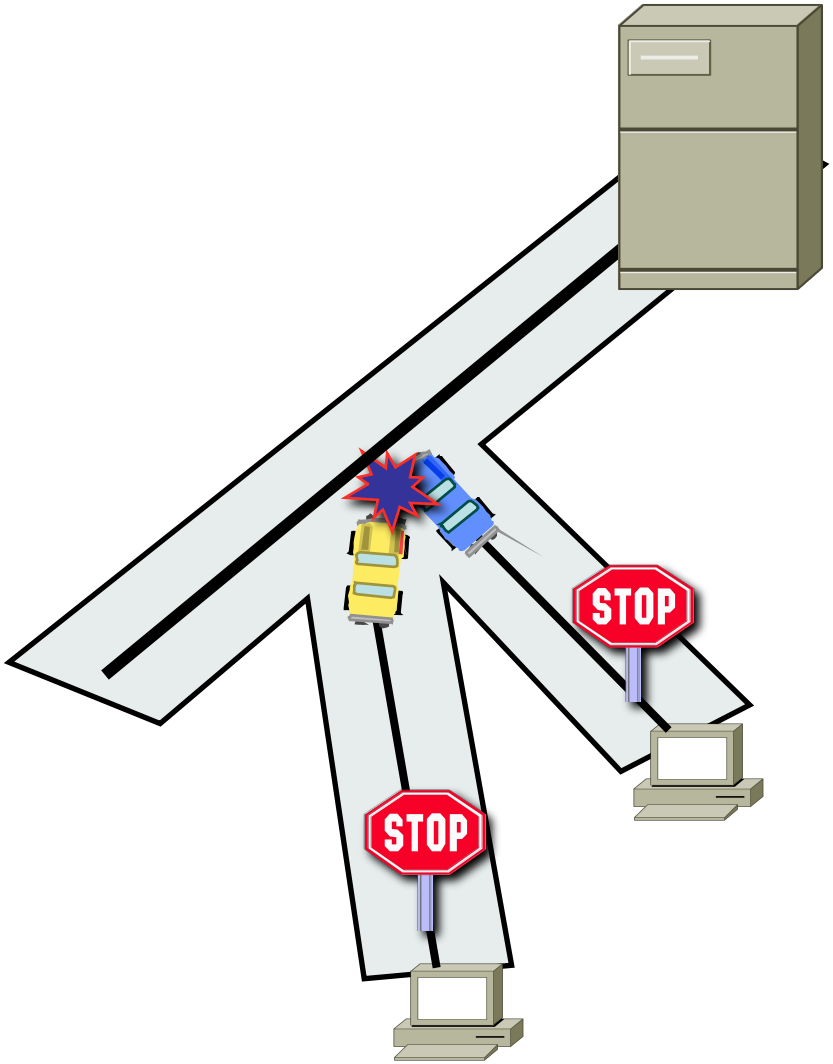
Bus Structure



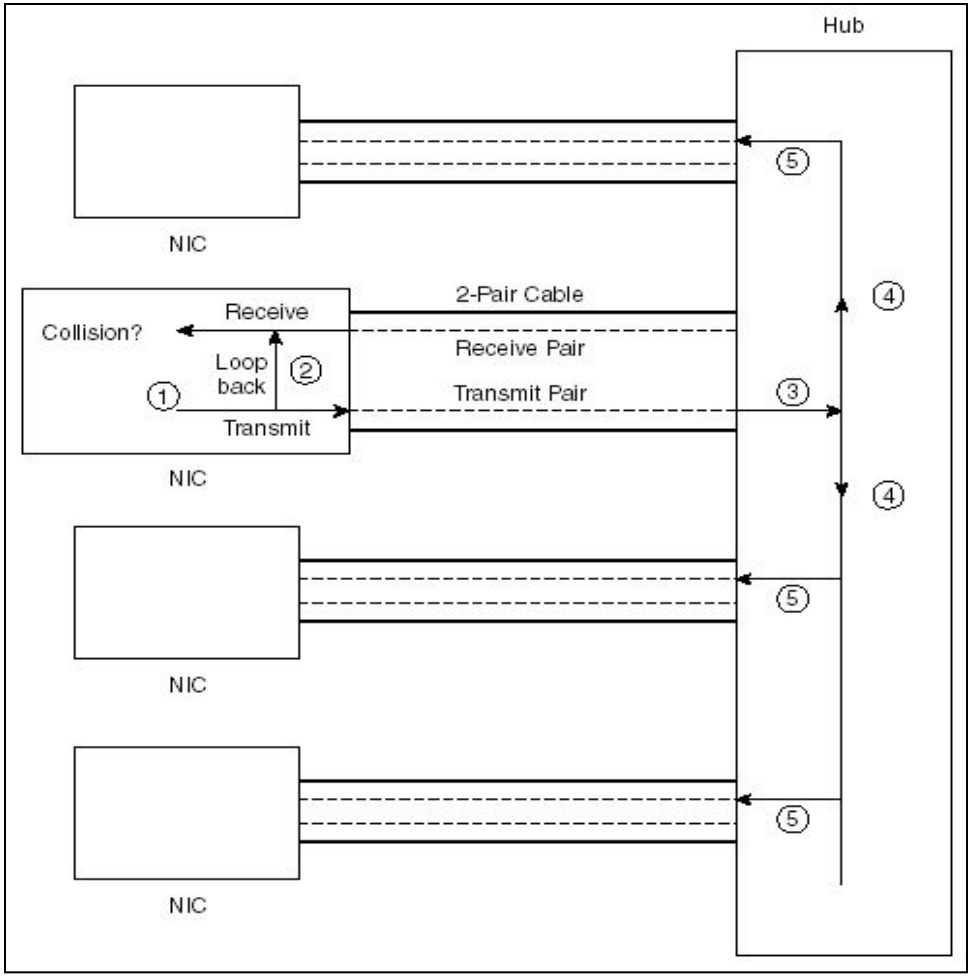
Star Structure

Коллизии и их преодоления

- Большое количество рабочих станций порождает большое число коллизий при попытках их подключения к сети.
- Для преодоления коллизий используется алгоритм CSMA/CD.

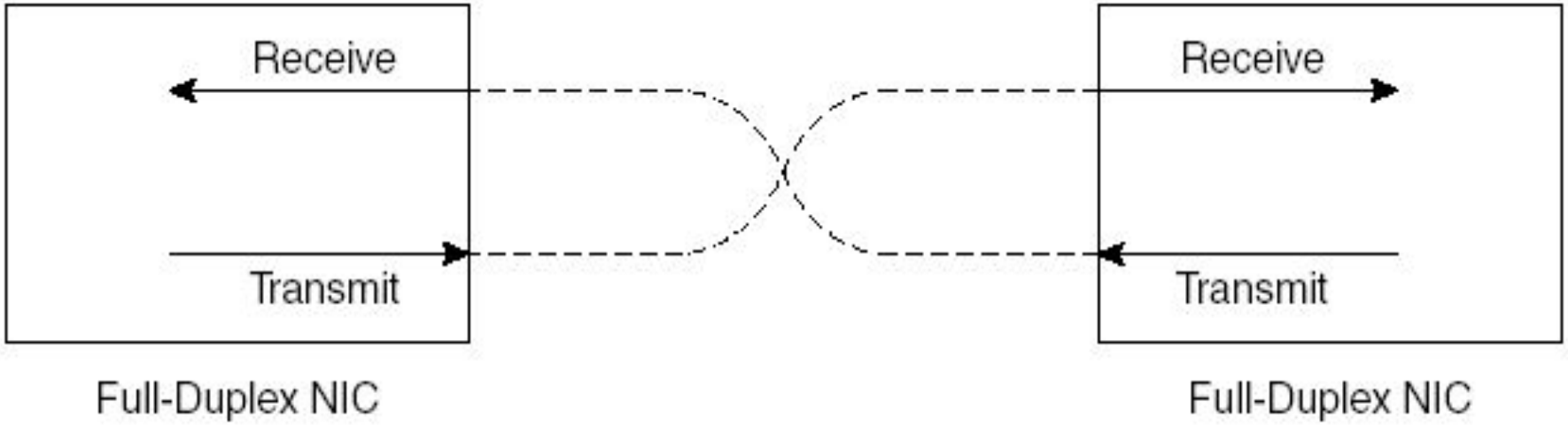


Hub operation



1. NIC sends a frame.
2.The NIC loops the sent frame onto its receive pair.
3. The hub receives the frame.
4. The hub sends the frame across an internal bus
5. The hub repeats the signal from each pair to all other devices.

Организация дуплексных связей



Преимущества дуплексного режима:

- ***Коллизии не возникают.***
- ***Отсутствует задержка ответа, связанная с ожиданием окончания передачи.***
- ***Скорость 10 Mbps доступна для каждой станции.***

Стандарты *Ethernet* и *Fast Ethernet*

Standard	*MAC Sublayer Specification*	*Maximum Cable Length*	*Cable Type*	*Pairs Required*
10Base5	802.3	500 m	50-Ohm thick coaxial cable	—
10Base2	802.3	185 m	50-Ohm thin coaxial cable	—
10BaseT	802.3	100 m	Category 3, 4, or 5 UTP	2
10BaseFL	802.3	2000 m	Fiber	1
100BaseTX	802.3u	100 m	Category 5 UTP	2
100BaseT4	802.3u	100 m	Category 3 UTP	4
100BaseT2	802.3u	100 m	Category 3, 4, or 5 UTP	2

Стандарты *Fast Ethernet* и *Gigabit Ethernet*

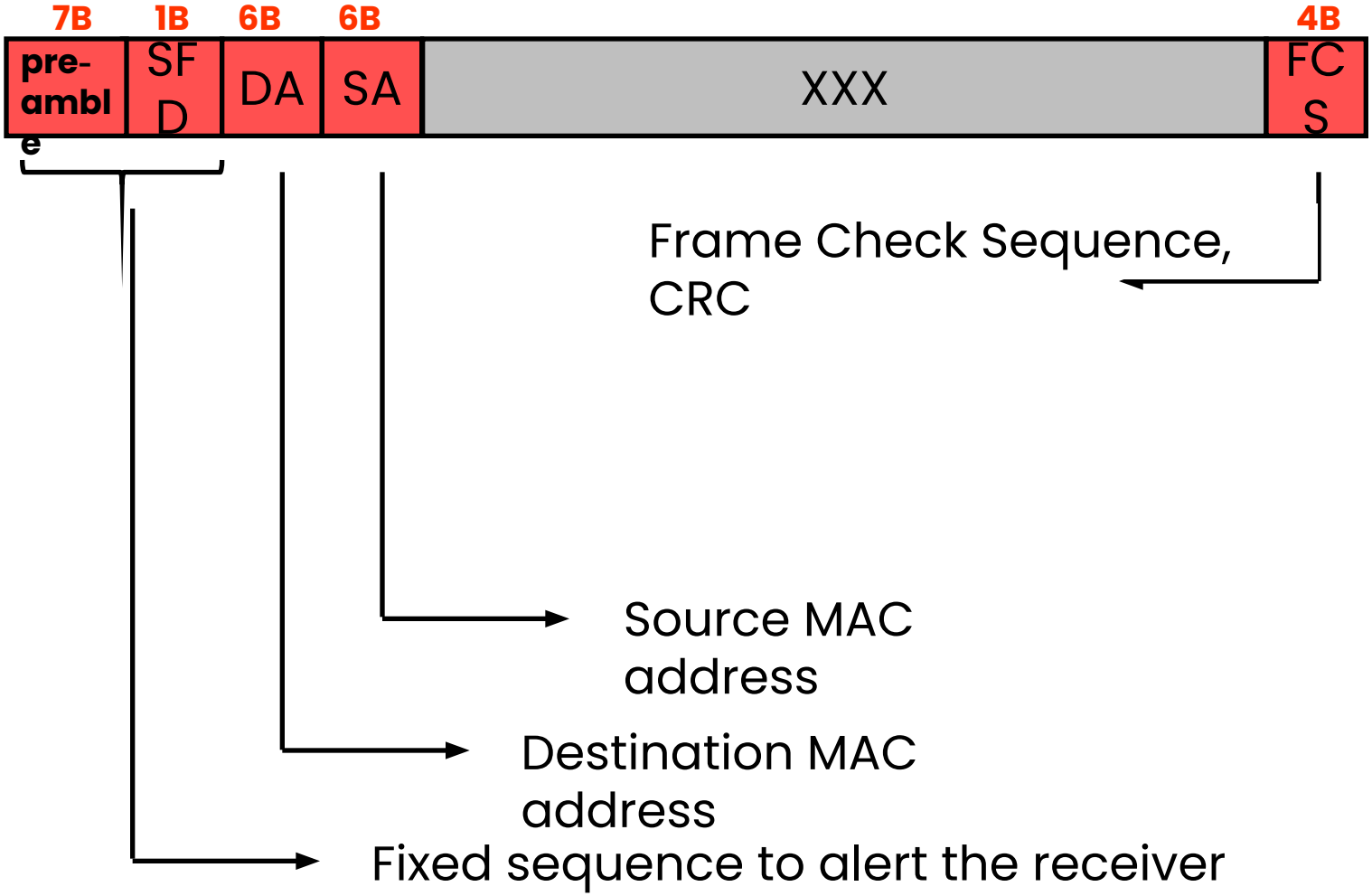
Standard	*MAC Sublayer Specification*	*Maximum Cable Length*	*Cable Type*	*Pairs Requir*
100BaseFX	**802.3u**	**400/2000 m**	**Multimode fiber**	**1**
100BaseFX	**802.3u**	**10,000m**	**Single-mode fiber**	**1**
1000BaseSX	**802.3z**	**220-550m**	**Multimode fiber**	**1**
1000BaseLX	**802.3z**	**3000m**	**Single-mode or multimode fiber**	**1**
1000BaseCX	**802.3z**	**25m**	**Shielded copper**	**2**
1000BaseT	**802.3ab**	**100m**	**Category 5 UTP**	**2**

Уровень звена данных

Ethernet:

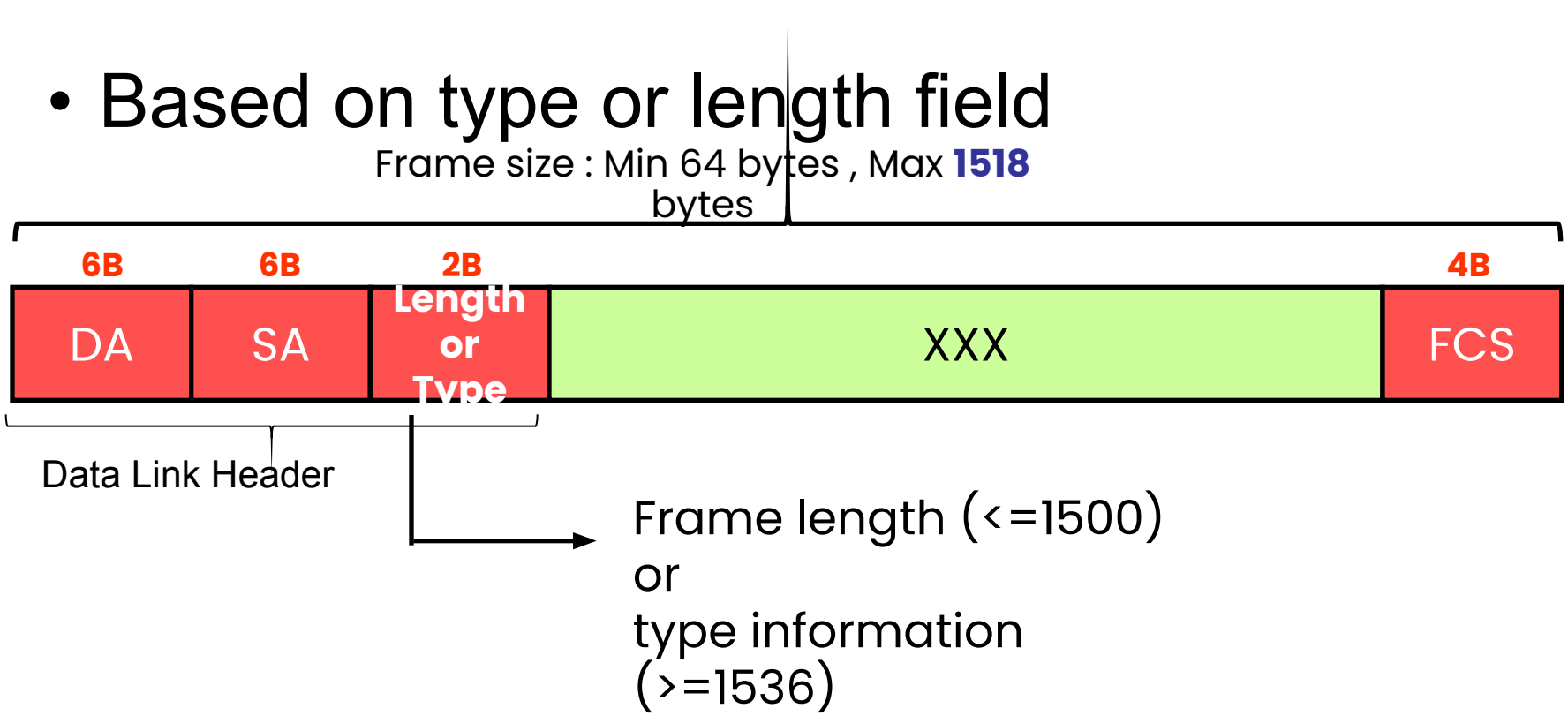
форматы кадров

Общий формат кадров

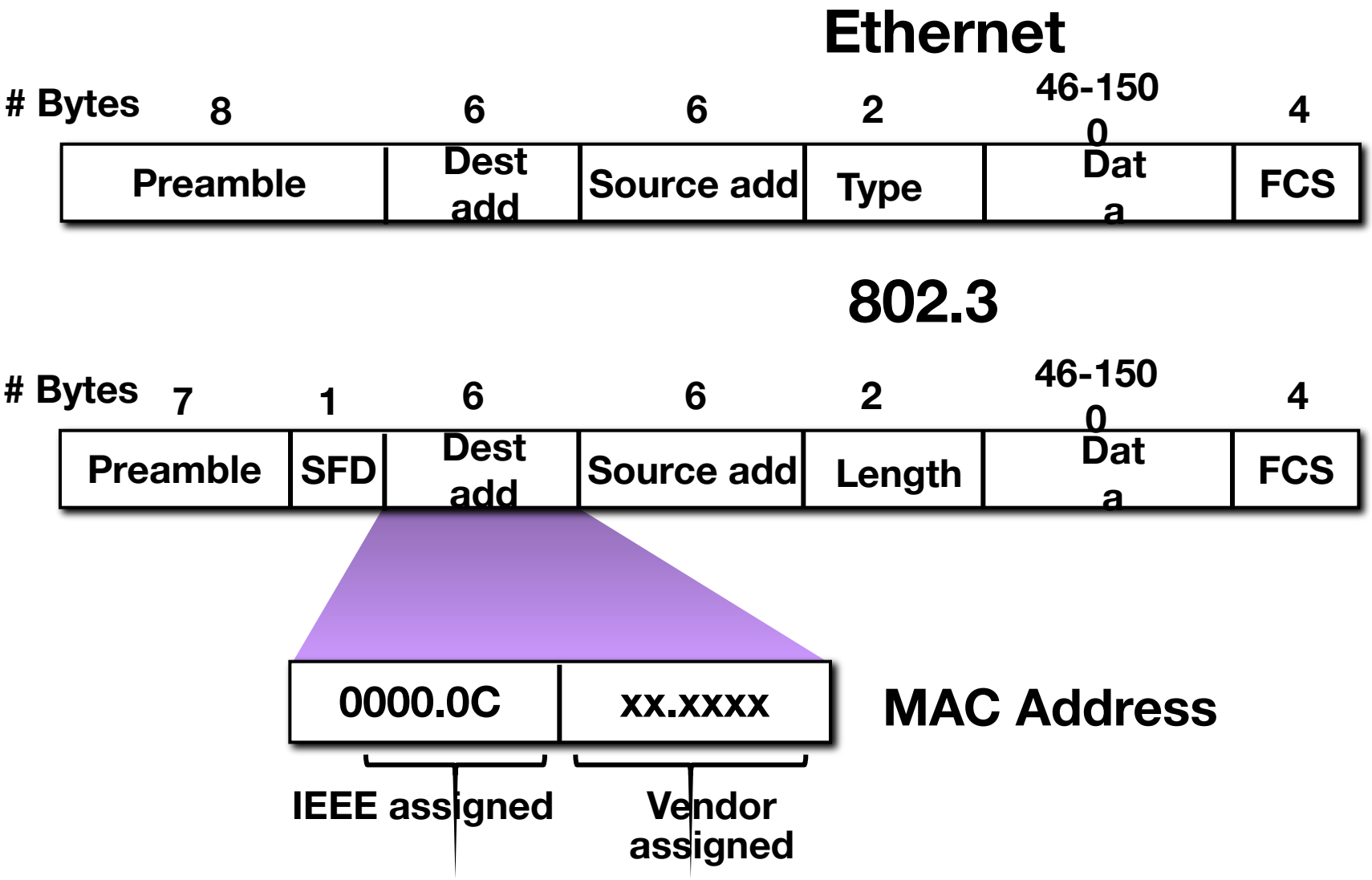


Формат кадра Ethernet по IEEE 802.3

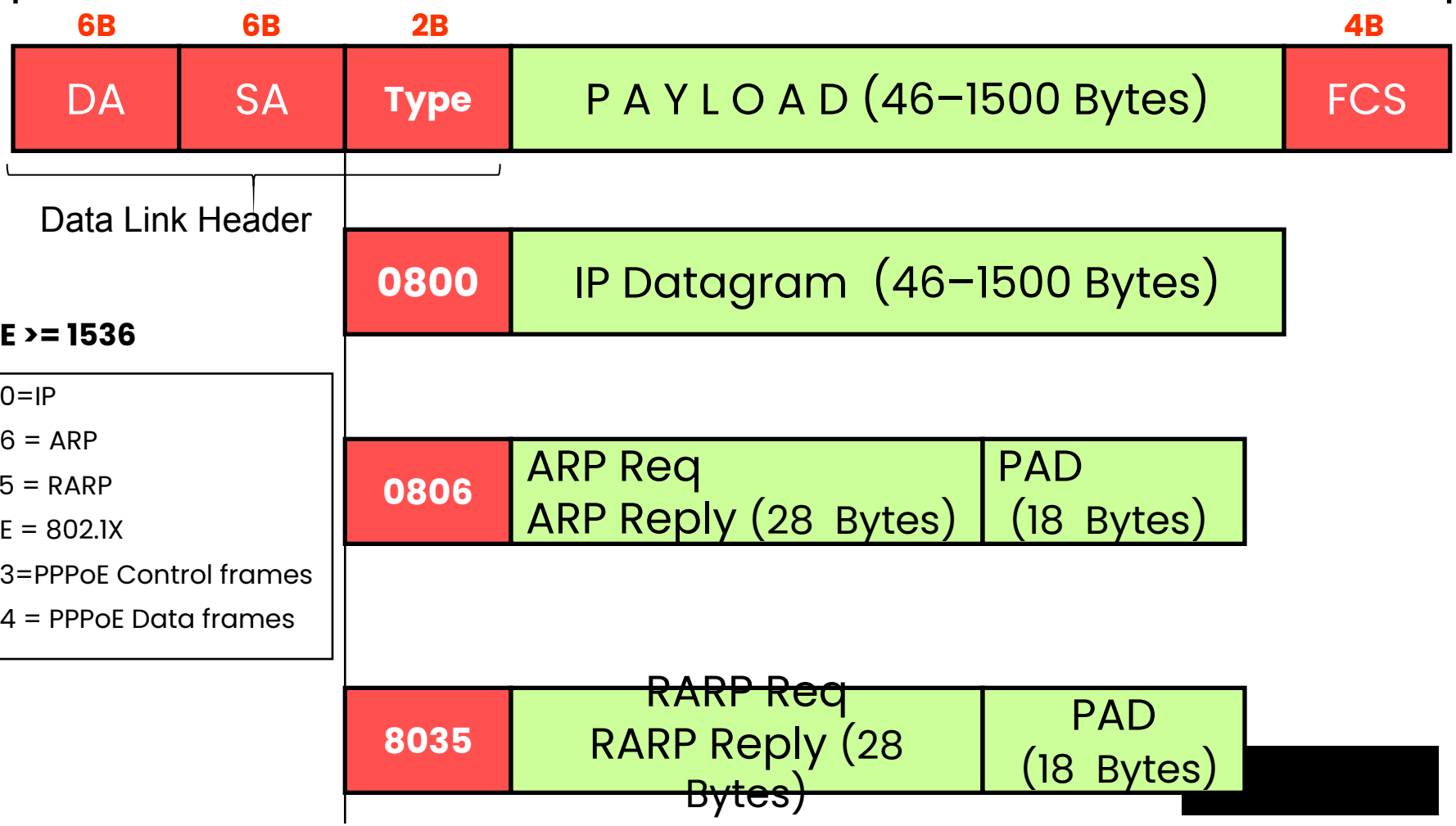
- Based on type or length field



Сравнение форматов



Кодирование поля «тип»



TYPE >= 1536

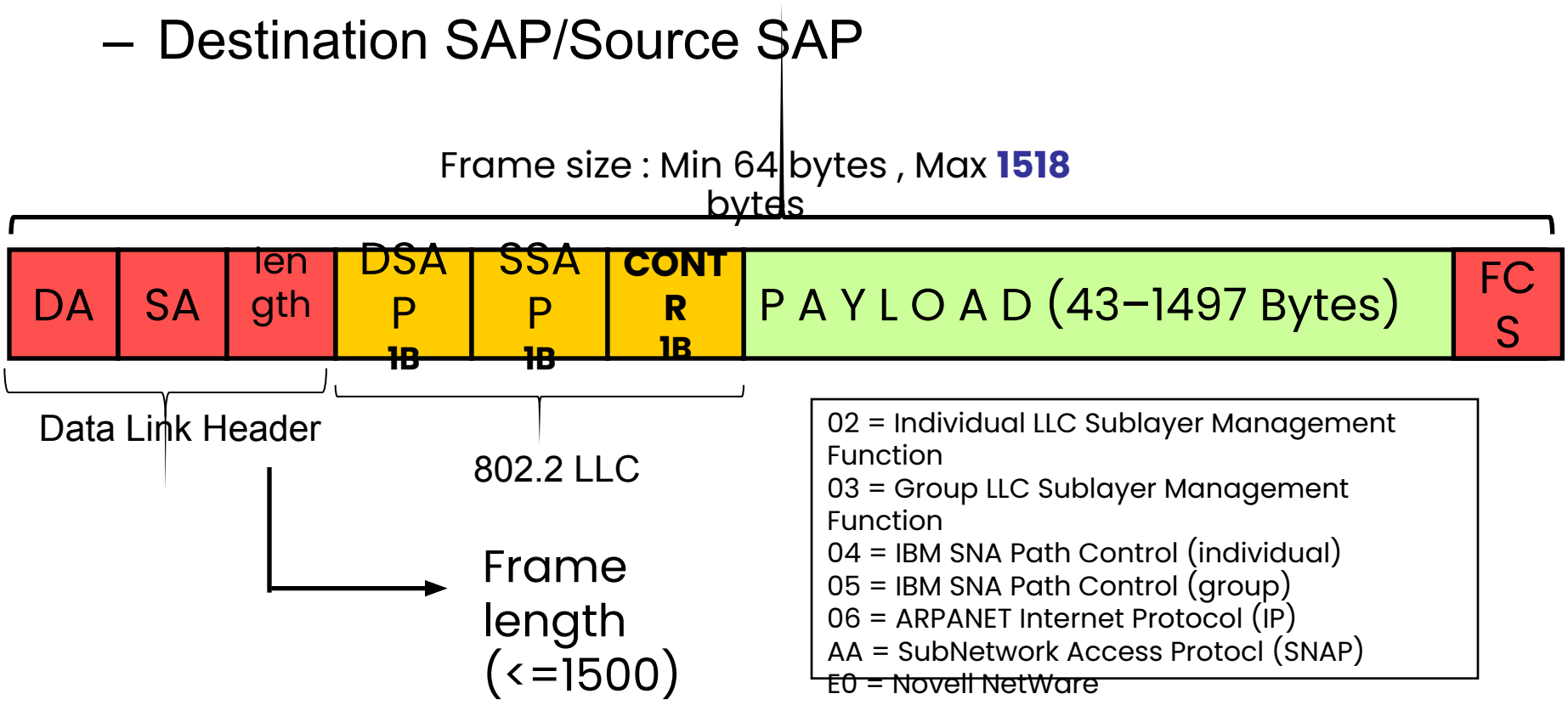
0x0800=IP
0x0806 = ARP
0x8035 = RARP
0x888E = 802.1X
0x8863=PPPoE Control frames
0x8864 = PPPoE Data frames

Правила формирования полей «длина» и «тип»

- Ethernet version 2 (Xerox) MAC frame
  - has Ethertype field
    - indicates which protocol is inside the data section
    - Value always > 05-DC hex.
- 802.3 has a Length or Type field
  - if < 05-DC IEEE802.3 Length field
  - if >= 05-DC IEEE802.3 Type field
    - Type field gives a protocol identification (same as Ethertype)
- 802.3 incorporates aspects of Ethernet version 2 and will replace it for high-speed Ethernet networks
  - Ethernet v2 is a valid 802.3 frame

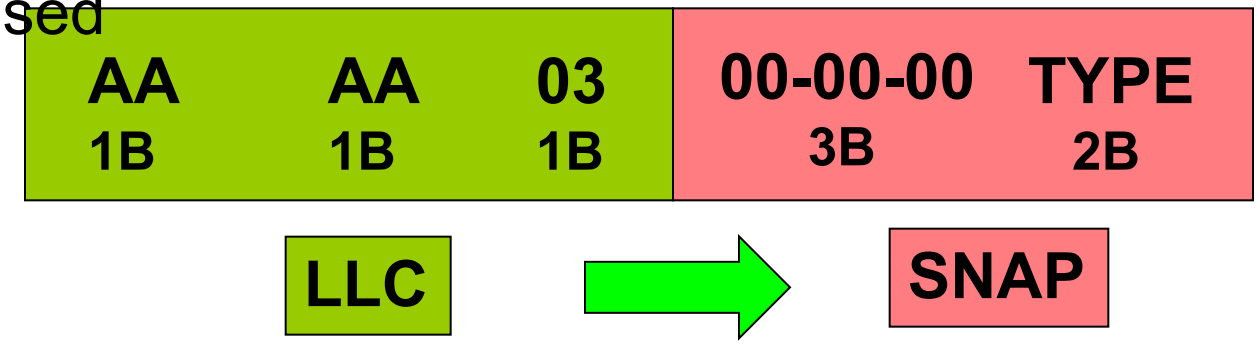
Формат кадра с заголовком 802.2 LLC

- Defining Service Access Points (SAPs)
- SAPs ensure that the same Network Layer protocol is used at the source and at the destination.
  - TCP/IP talks to TCP/IP, IPX/SPX talks to IPX/SPX,…
  - Destination SAP/Source SAP



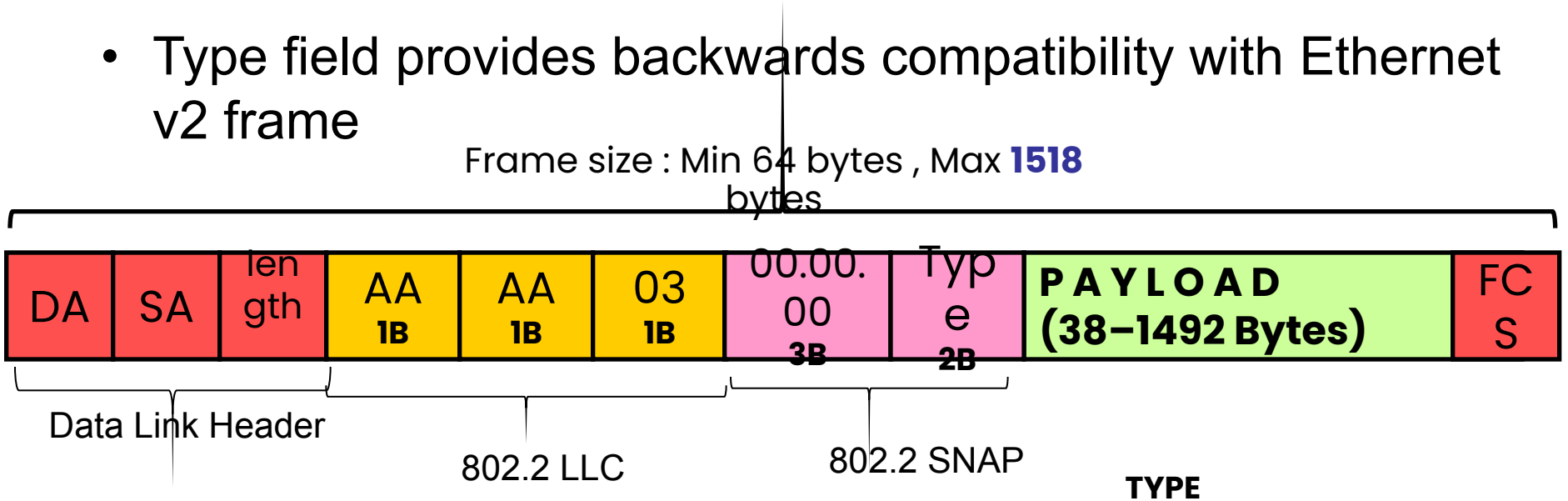
Формат заголовка IIEE 802.3 SNAP

- Due to growing number of applications using the IEEE LLC 802.2 header, an extension was made.
  - Introduction of the IEEE 802.3 Sub Network Access Protocol (SNAP) header
- SSAP=H'AA, DSAP=H'AA indicates that a SNAP-header is used



Формат кадра с заголовками 802.2 LLC/ 802.3 SNAP header

- Type field provides backwards compatibility with Ethernet v2 frame



TYPE

0x0800=IP

0x0806 = ARP

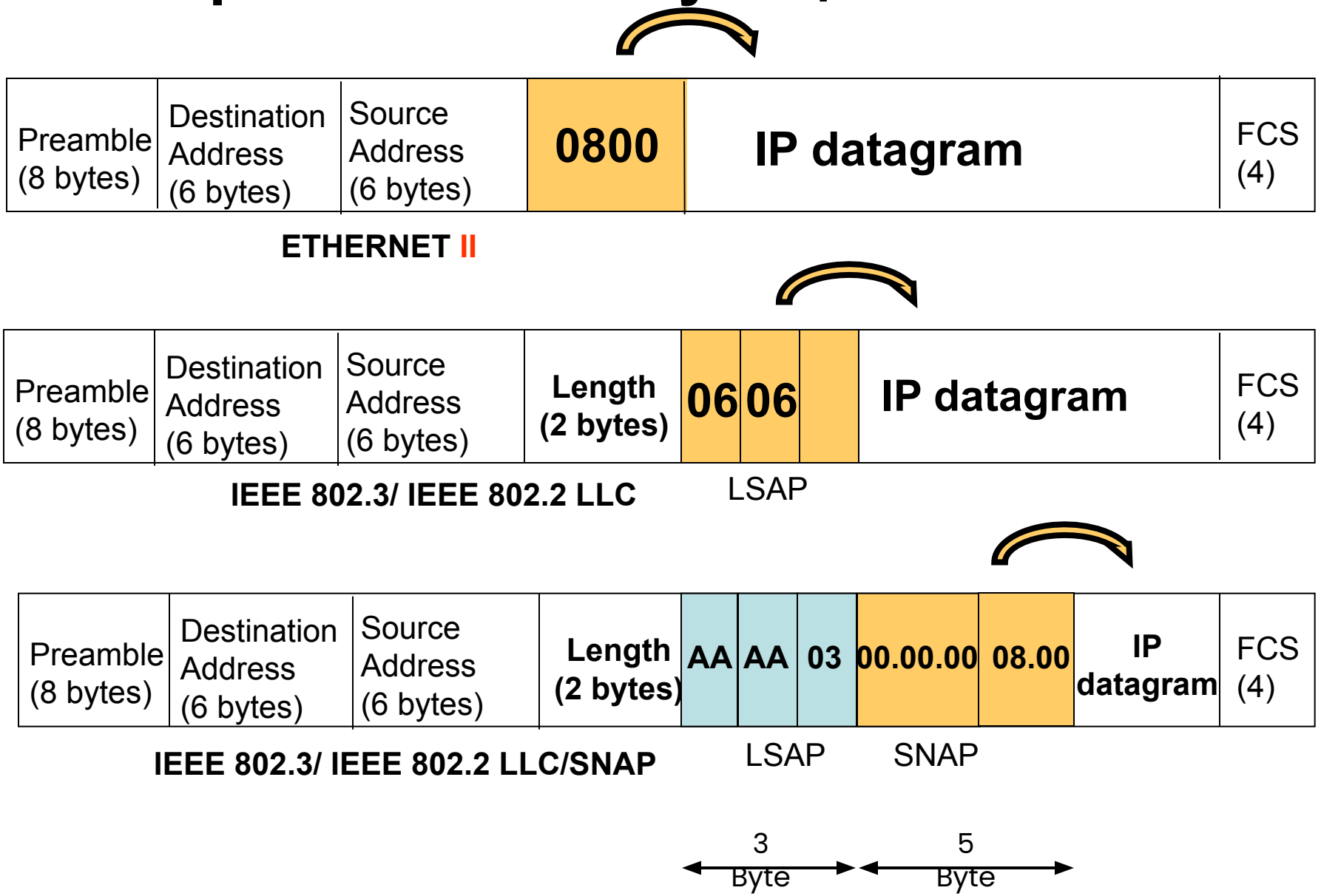
0x8035 = RARP

0x888E = 802.1X

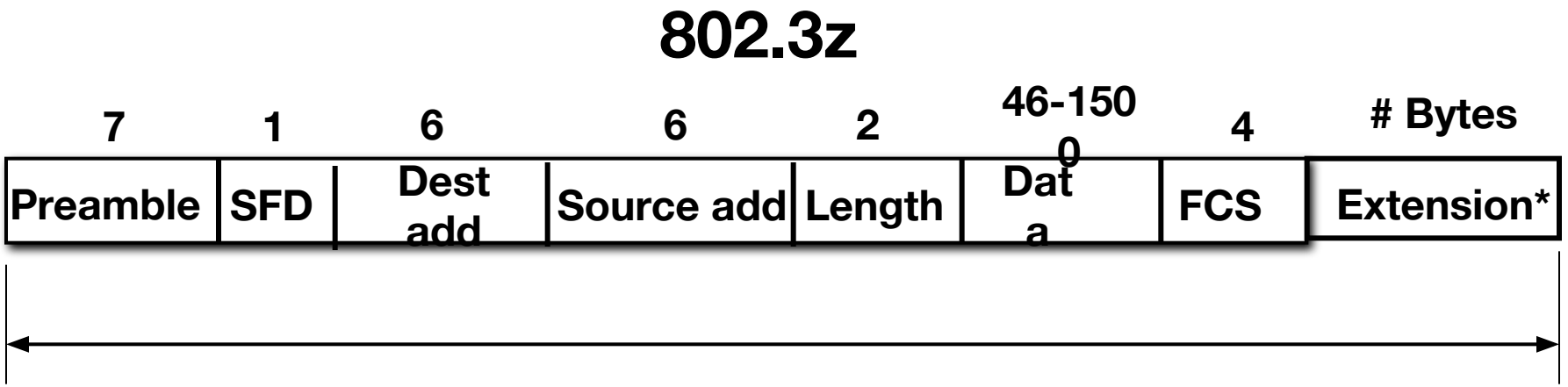
0x8863=PPPoE Control frames

0x8864 = PPPoE Data frames

Варианты инкапсуляции IP пакета



Gigabit Ethernet Frame Format



416 bytes for 1000Base-X

520 bytes for 1000Base-T

* Поле кадра «extension» автоматически отбрасывается во время обработки кадра Gigabit Ethernet.

Адресация данных в CAN

Individual/Group Address bit

Unicast

Binary: 00110101 01111011 00010010 00000000 00000000 00000001
Hex: AC-DE-48-00-00-80

Individual/Group Address bit

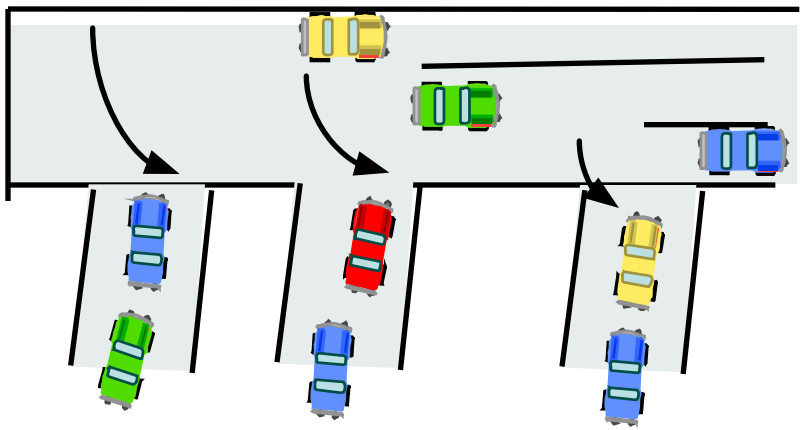
Multicast

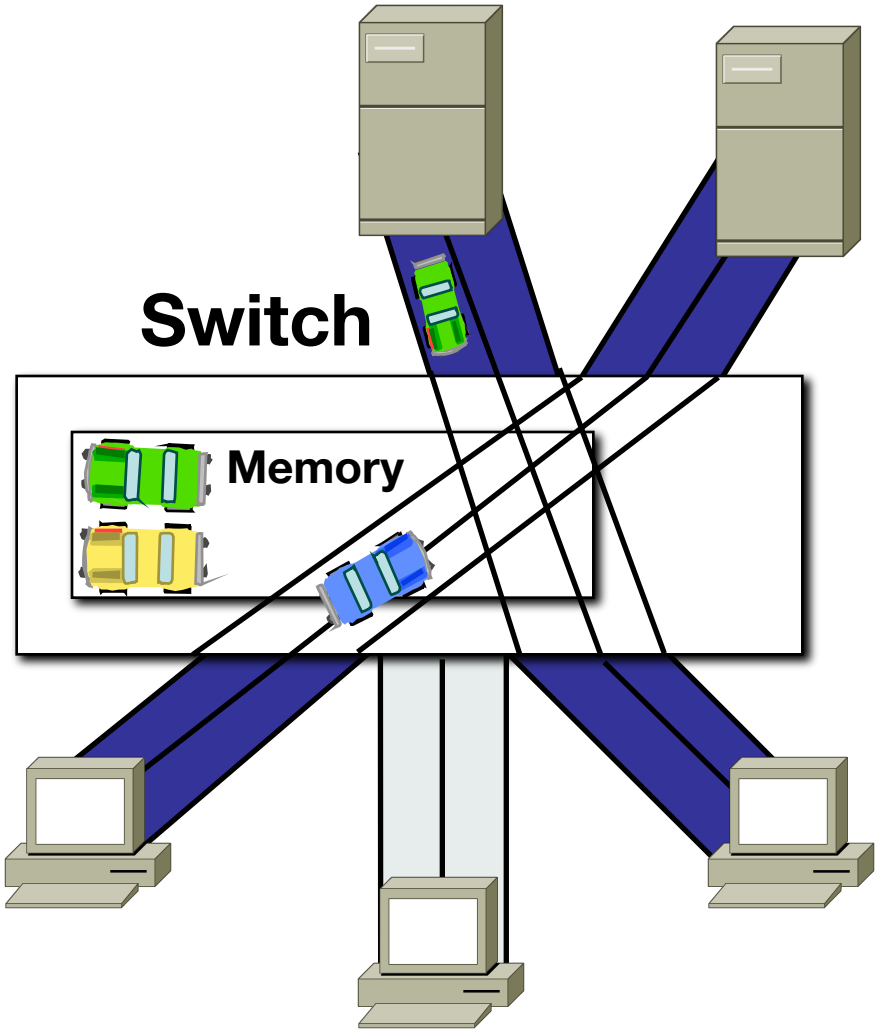
Binary: 10000000 00000000 00000101 10101010 01000100 00000001
Hex: 01-00-C0-55-22-80

Broadcast

Binary: 11111111 11111111 11111111 11111111 11111111 11111111
Hex: FF-FF-FF-FF-FF-FF

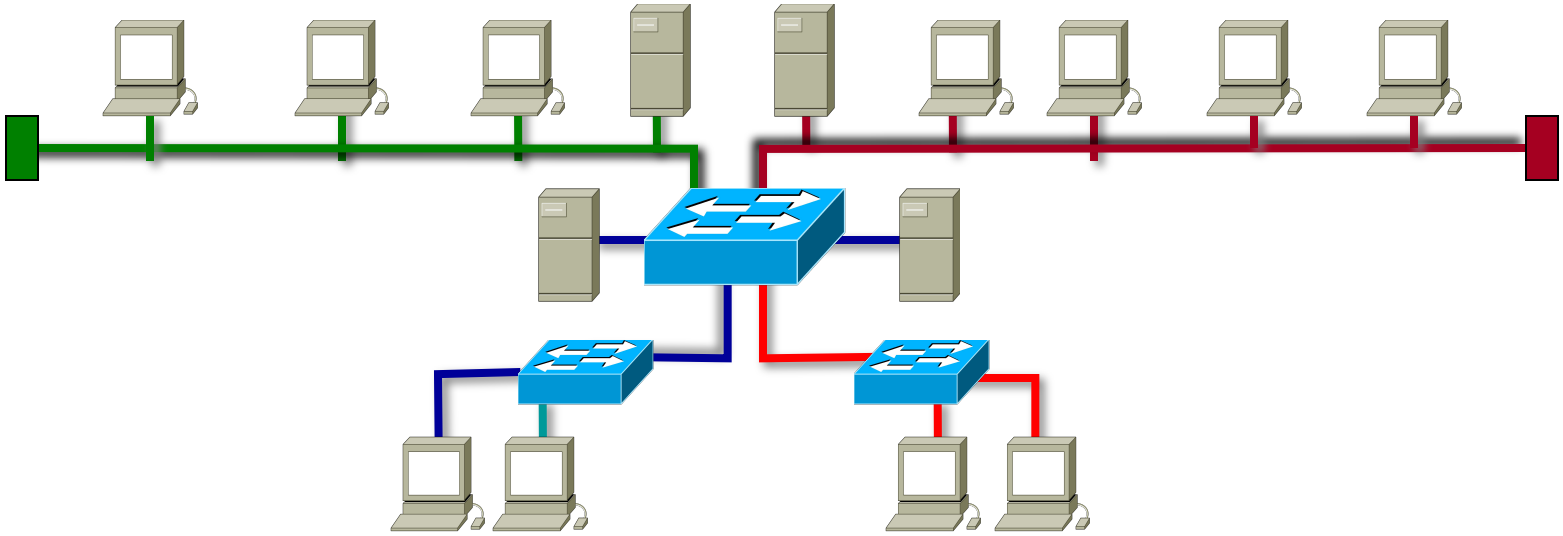
Коммутация по физическим адресам





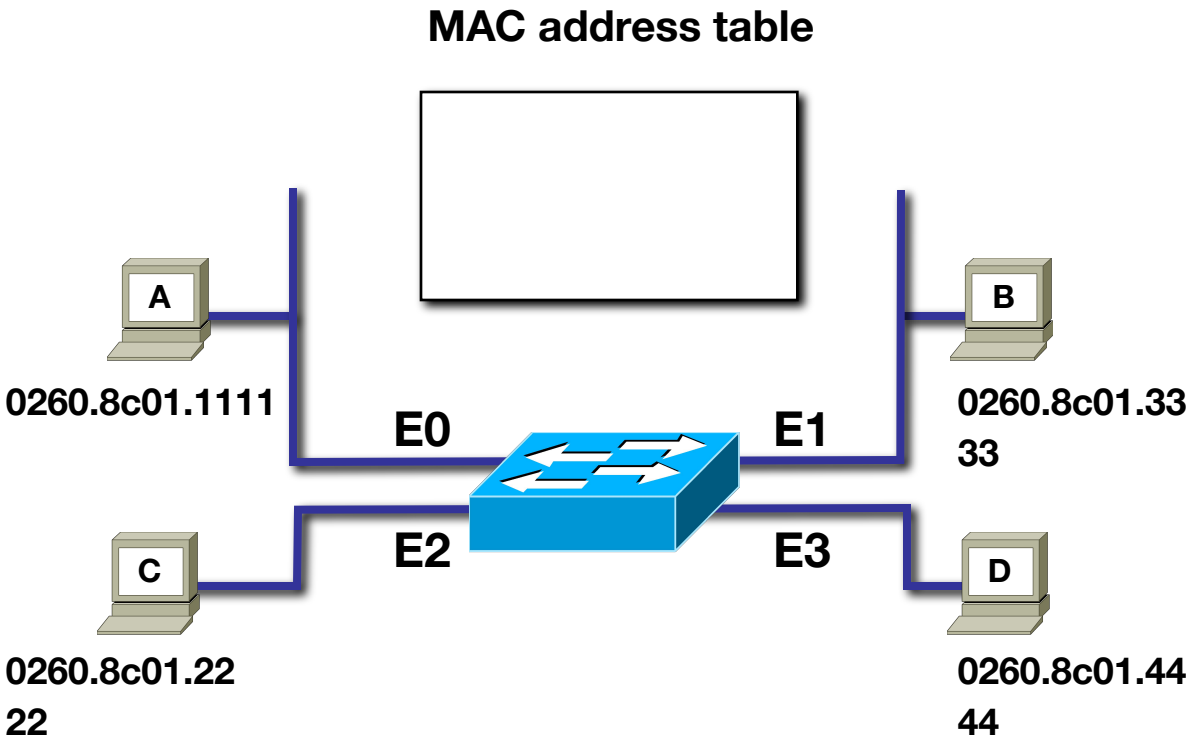
- В каждом сегменте могут возникать свои собственные коллизии.
- В режиме broadcast коммутатор рассылает пакеты всем приемникам

Три процедуры при коммутации пакетов



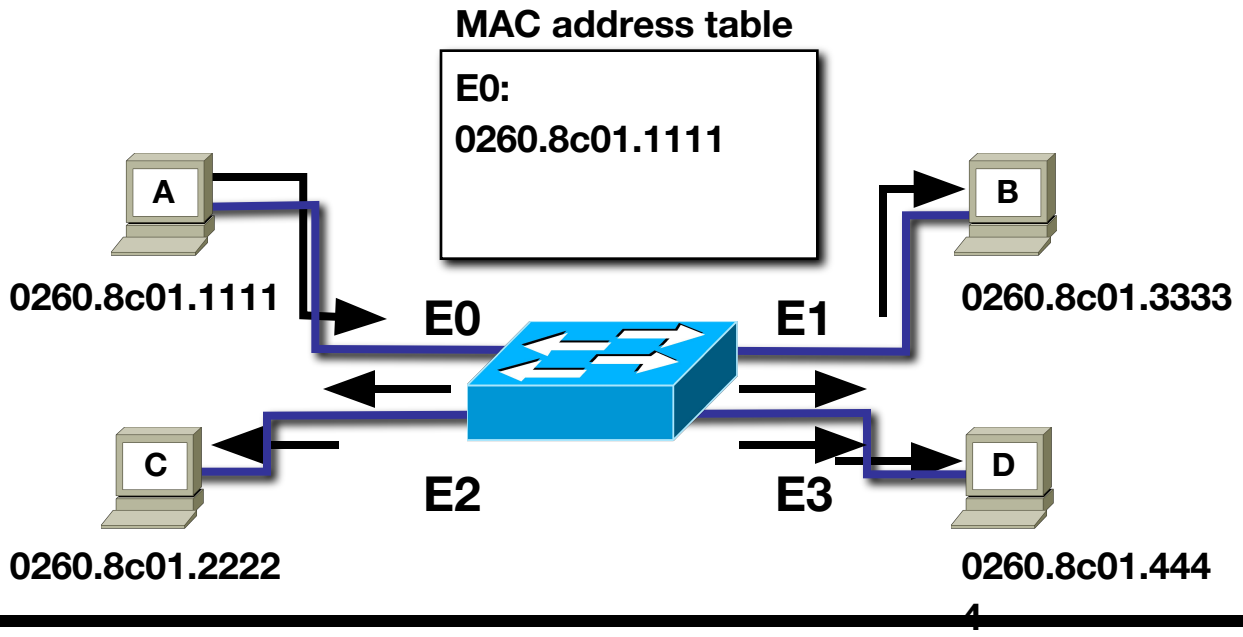
- Изучение адресов уровня звена данных.
- Решение о выборе класса пересылки пакетов.
- Исключение петель в маршруте соединения.

How Switches Learn Host Locations



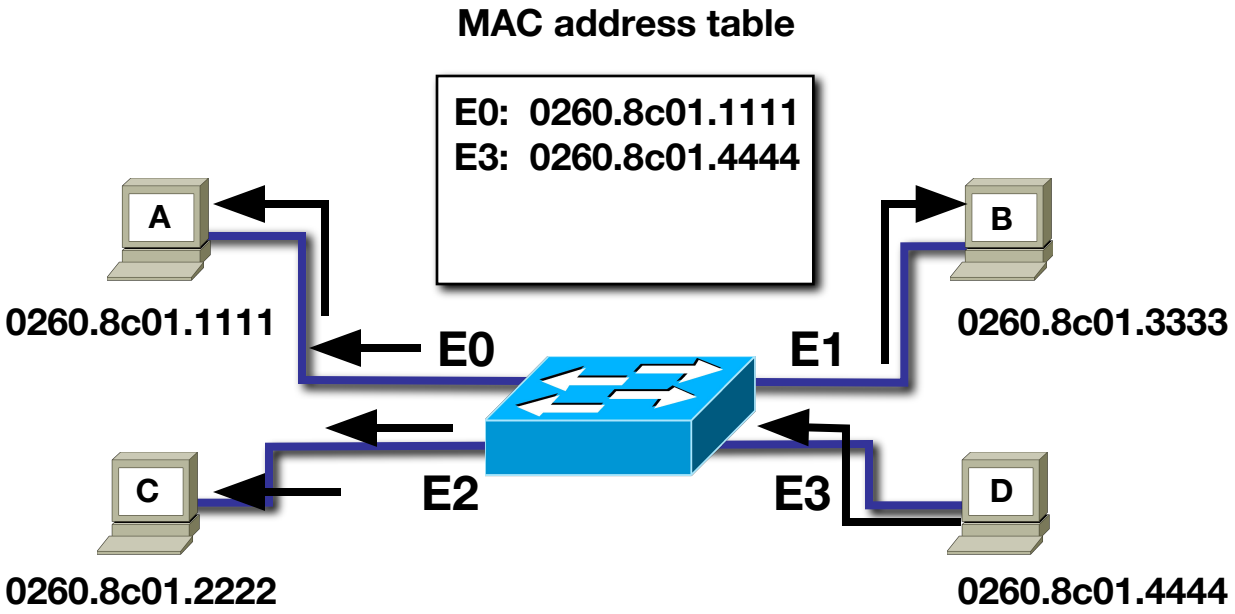
- В начале инсталляции сети таблица MAC адресов (таблица коммутации) пуста.

How Switches Learn Hosts Locations



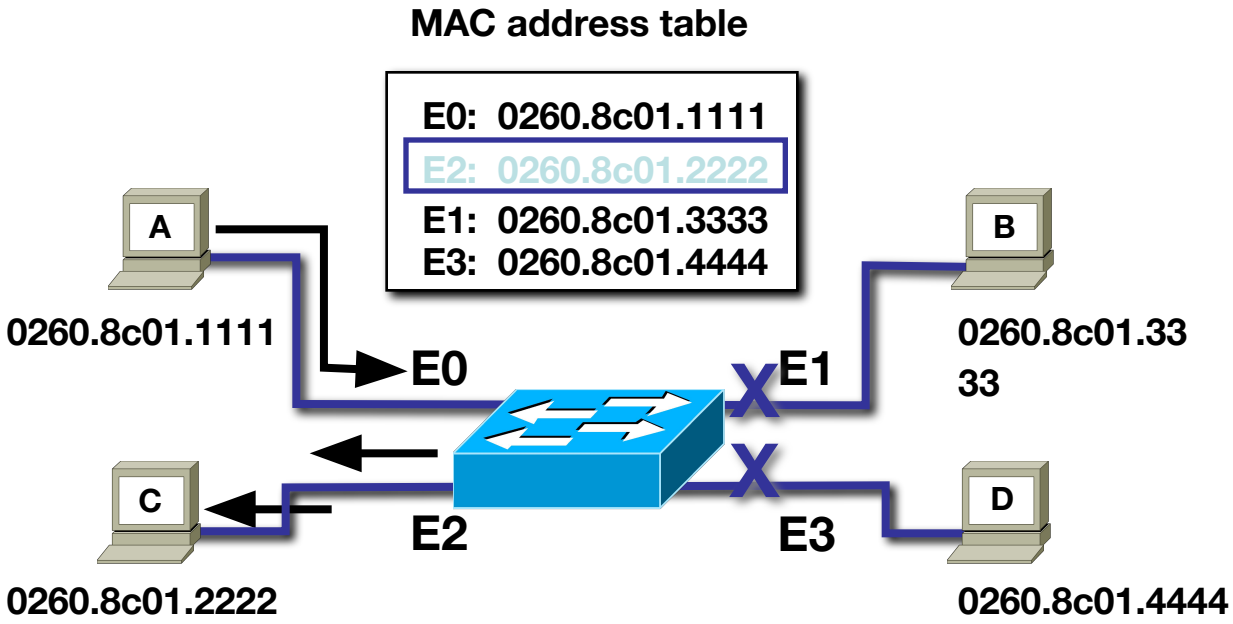
- *Станция А передает кадр станции С. В кадре станция А указывается как свой MAC адрес, так и MAC адрес станции С.*
- *Switch читает MAC адрес станции А, как адрес отправителя данных, получая от нее кадр из порта E0 и заносит его в таблицу коммутации.*
- *Поскольку в таблице еще нет адреса станции С, то Switch в режиме broadcast рассылает всем приемникам кадр, в котором просит сообщить их свои MAC адреса.*

How Switches Learn Host Locations



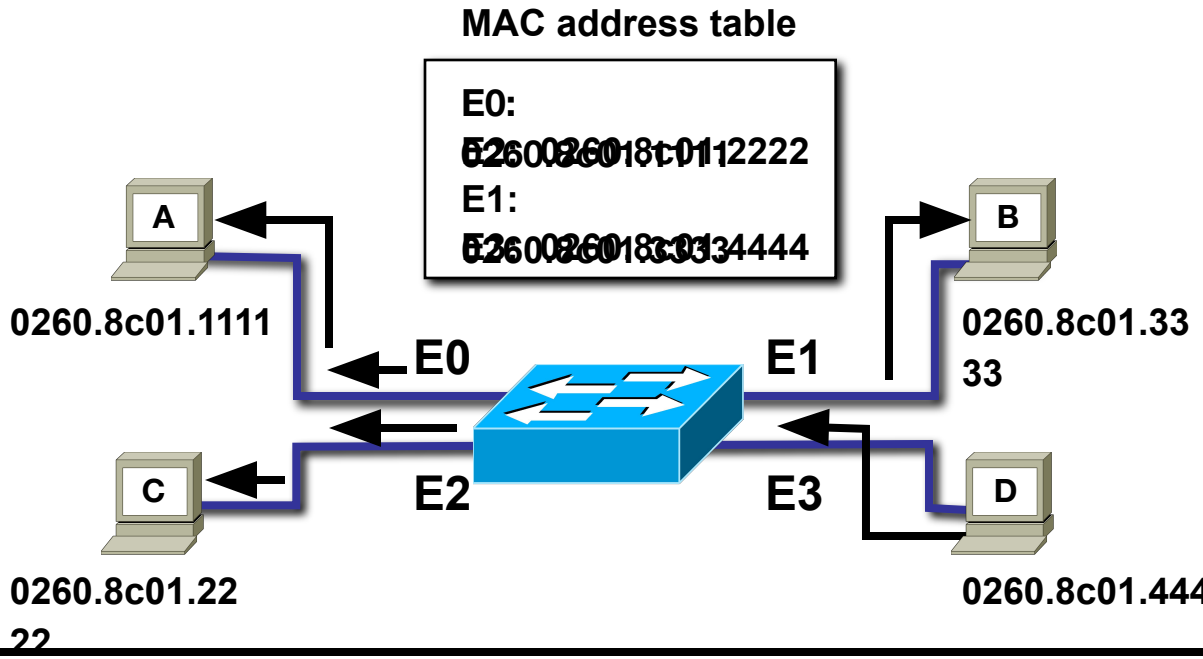
- *Станция D посылает кадр со своим MAC адресом и Switch заносит этот адрес в таблицу коммутации.*
- *Аналогично станция B посылает кадр со своим MAC адресом и Switch также заносит этот адрес в таблицу коммутации.*
- *Наконец станция C посылает кадр со своим MAC адресом, Switch заносит этот адрес в таблицу коммутации и обнаруживает требуемый адрес приемника данных от станции A.*

How Switches Filter Frames



- *Switch пересылает кадр, полученный от станции A из порта E0, в порт E2, откуда был получен кадр с MAC адресом станции C.*
- *Адрес пересылки оказался определенным, и кадр передан по назначению.*

Broadcast and Multicast Frames



- *Станция D передает кадр в режиме broadcast, или multicast.*
- *Switch распознает кадр, предназначенный для всеобщей рассылки, и отправляет его во все порты.*
- *Кадр, предназначенный для многоадресной рассылки, рассылается в соответствии со списком адресов, содержащихся в этом кадре.*

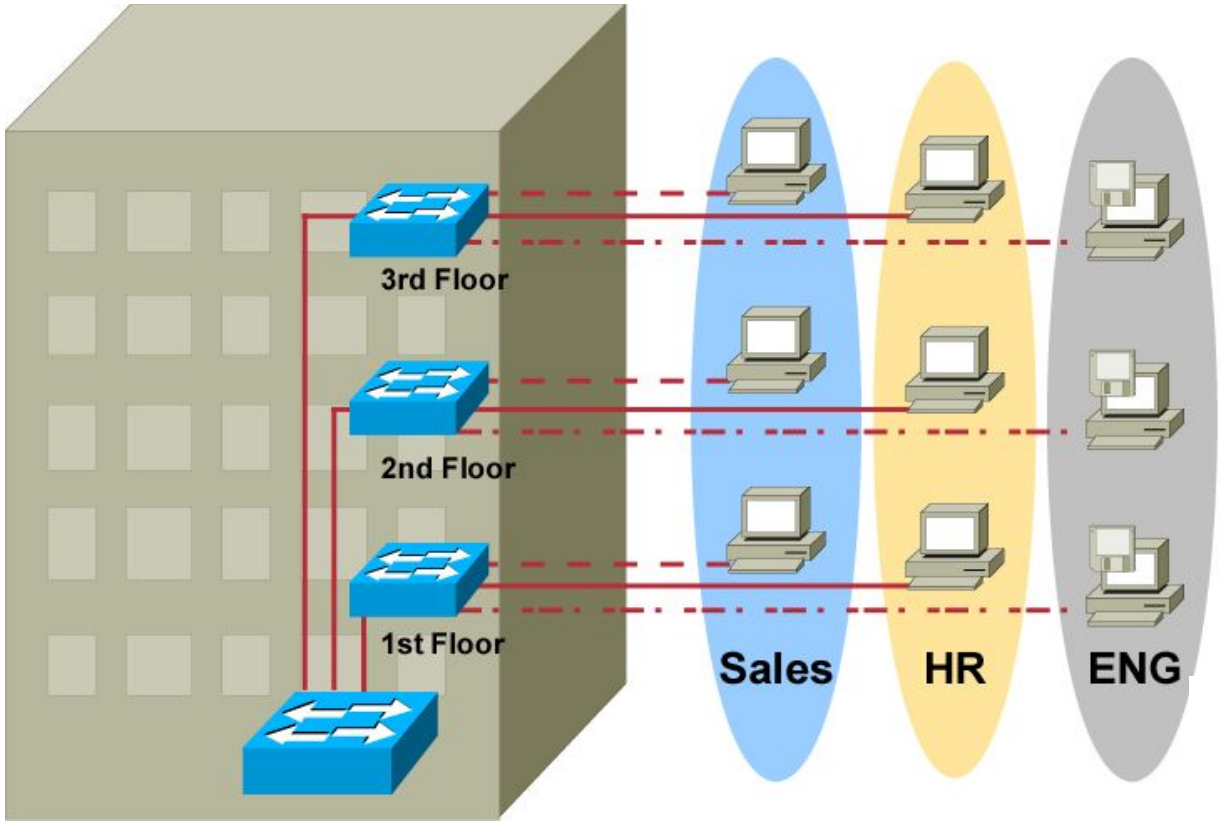
Ethernet:

организация виртуальных локальных сетей

(VLAN)

Иллюстрация организации

VLANs

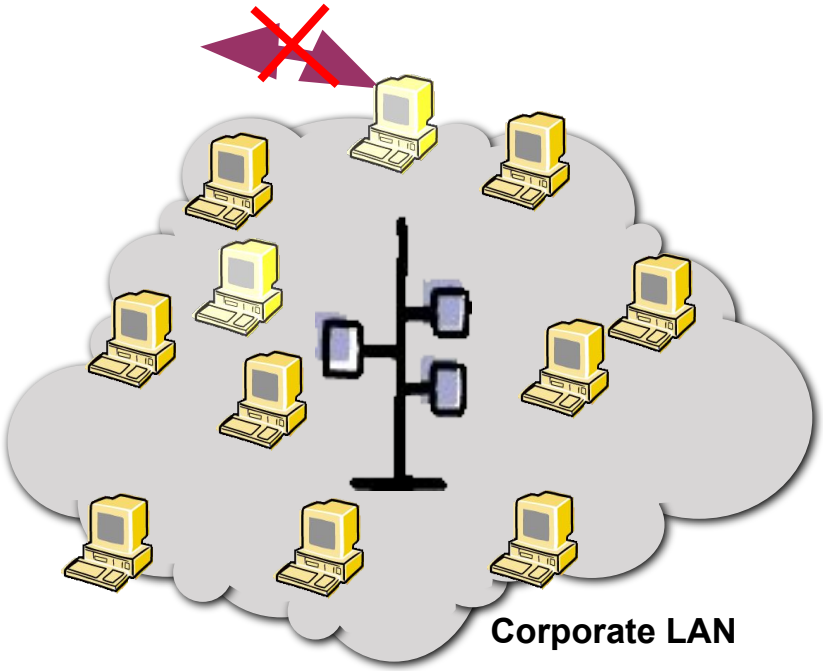


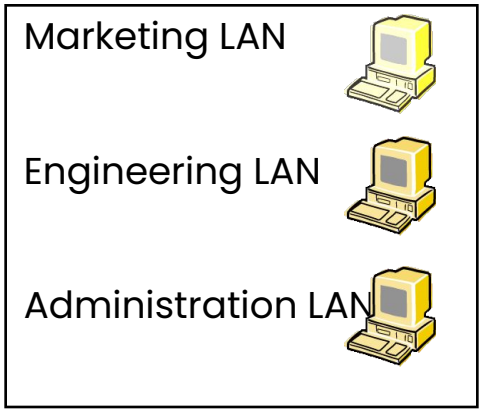
- Segmentation
- Flexibility
- Security

VLAN = Broadcast Domain = Logical Network (Subnet)

Определение VLAN

- Virtual Local Area Network VLAN
  - Used to separate the physical LAN into logical LANs
    - Logical broadcast / multicast domain
    - Virtual
  - Inter-VLAN communication: only via higher-layer devices (e.g. IP routers)
  - LAN membership defined by the network manager
    - Virtual





Преимущества VLAN

- Performance
  - VLANs free up bandwidth by limiting traffic.
- Formation of Virtual Workgroups
  - Users and resources that communicate frequently with each other can be grouped into a VLAN, regardless of physical location.
- Simplified Administration
  - Adding or moving nodes => can be dealt with quickly and conveniently from the management console rather than the wiring closet
- Reduced Cost
  - Use of VLANs can eliminate the need for expensive routers
  - With a VLAN-enabled adapter, a server can be a member of multiple VLANs.
- Security
  - VLANs create virtual boundaries that can only be crossed through a router.

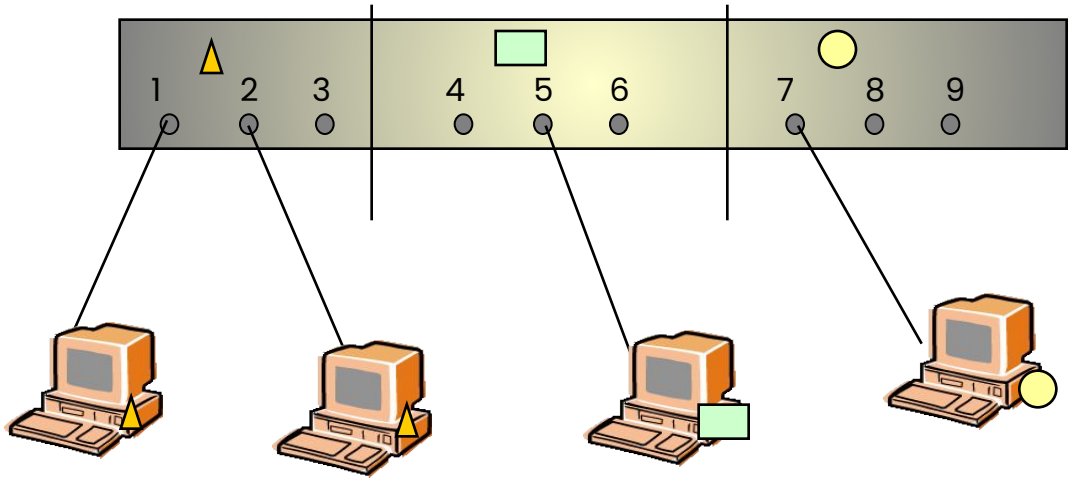
Способы организации VLAN

- VLAN can be distinguished by the method used to indicate membership when a packet travels between switches.
  - Implicit
  - Explicit
- VLAN membership can be classified by
  - Port,
  - Protocol type
  - MAC address
  - IP address
- IEEE 802.1Q
  - Explicit
    - 802.1Q tag
  - Implicit
    - Port based
    - Port and Protocol based

VLAN 1 уровня: по порту подключения

- Membership in a VLAN is defined based on the ports that belong to the VLAN.
  - Also refered to as Port switching
- Does not allow user mobility
- Does not allow multiple VLANs to include the same physical segment (or switch port)

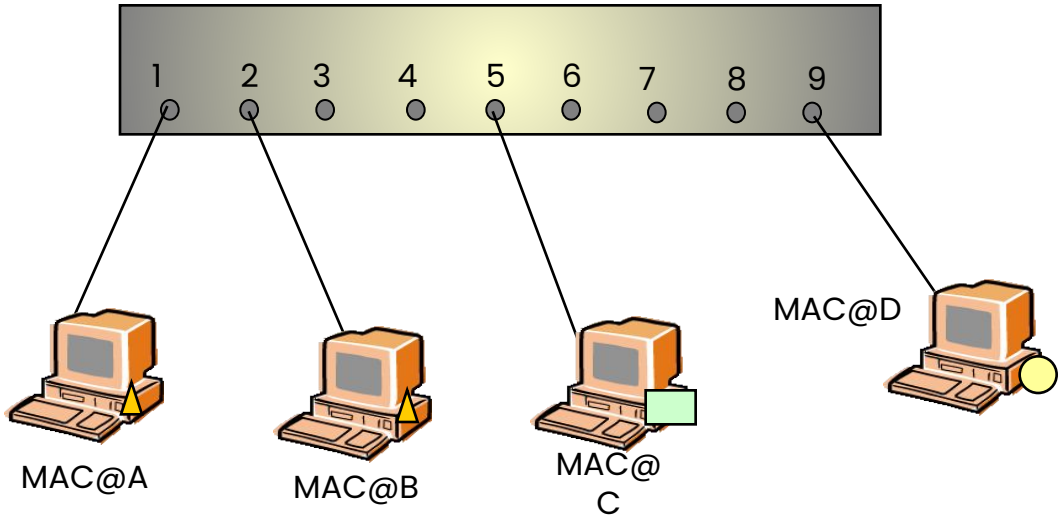
PORT	VLAN
1	▲
2	▲
5	▭
7	○



VLAN 2 уровня: по MACадресу

- Membership in a VLAN is based on the MAC address of the workstation.
  - The switch tracks the MAC addresses which belong to each VLAN
- Provides full user movement
  - Clients and server always on the same LAN regardless of location
- Disadvantages
  - Too many addresses need to be entered and managed
  - Notebook PCs change docking stations

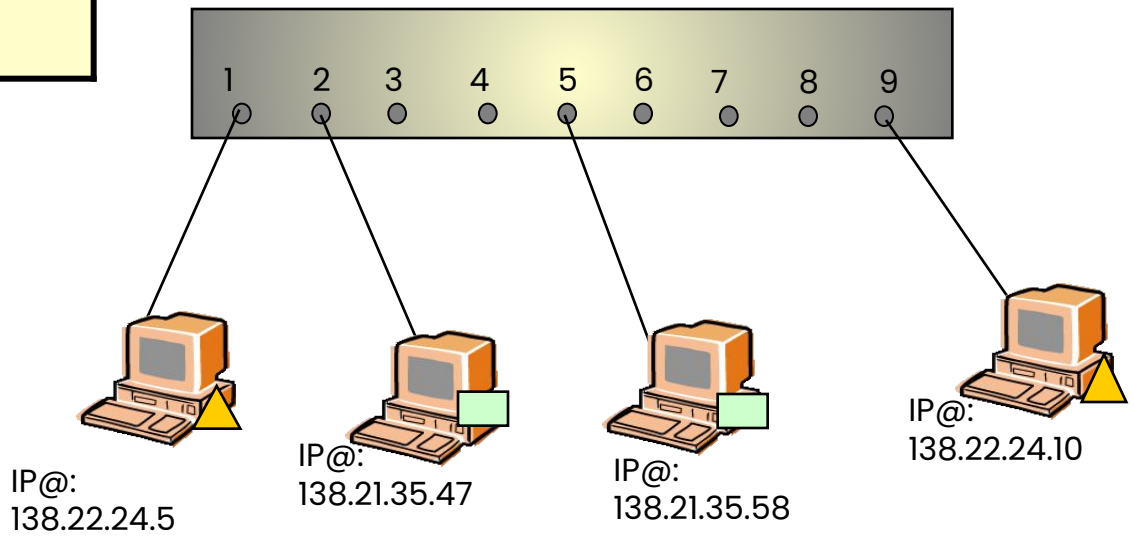
MAC@	VLAN
MAC@A	
MAC@B	
MAC@C	
MAC@D	



VLAN 3 уровня: по маске подсети IP

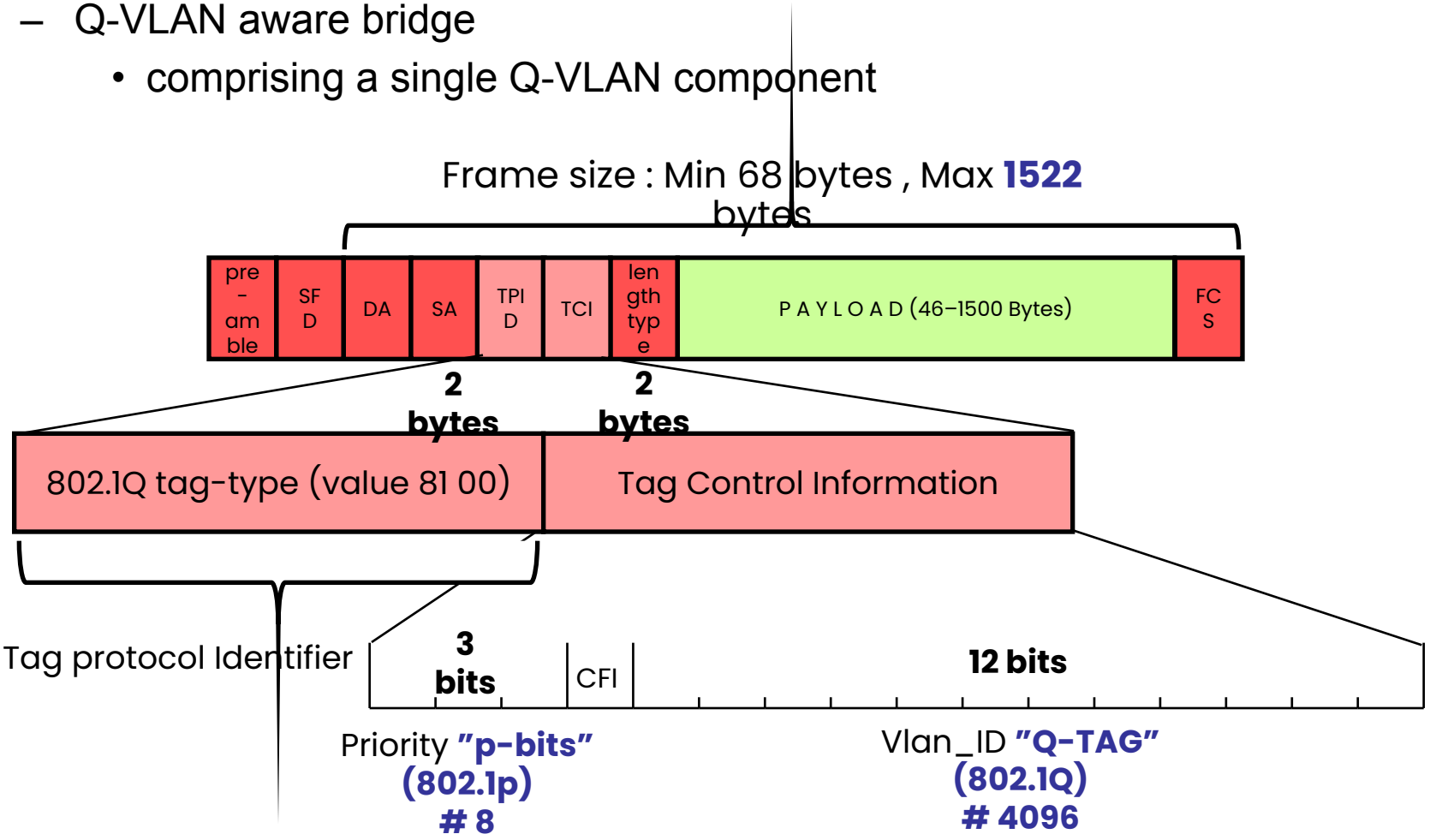
- The network IP subnet address (layer 3 header) can be used to classify VLAN membership

SUBNET /MASK	VLAN
138.22.24.0/24	▲
138.21.35.0/24	▭



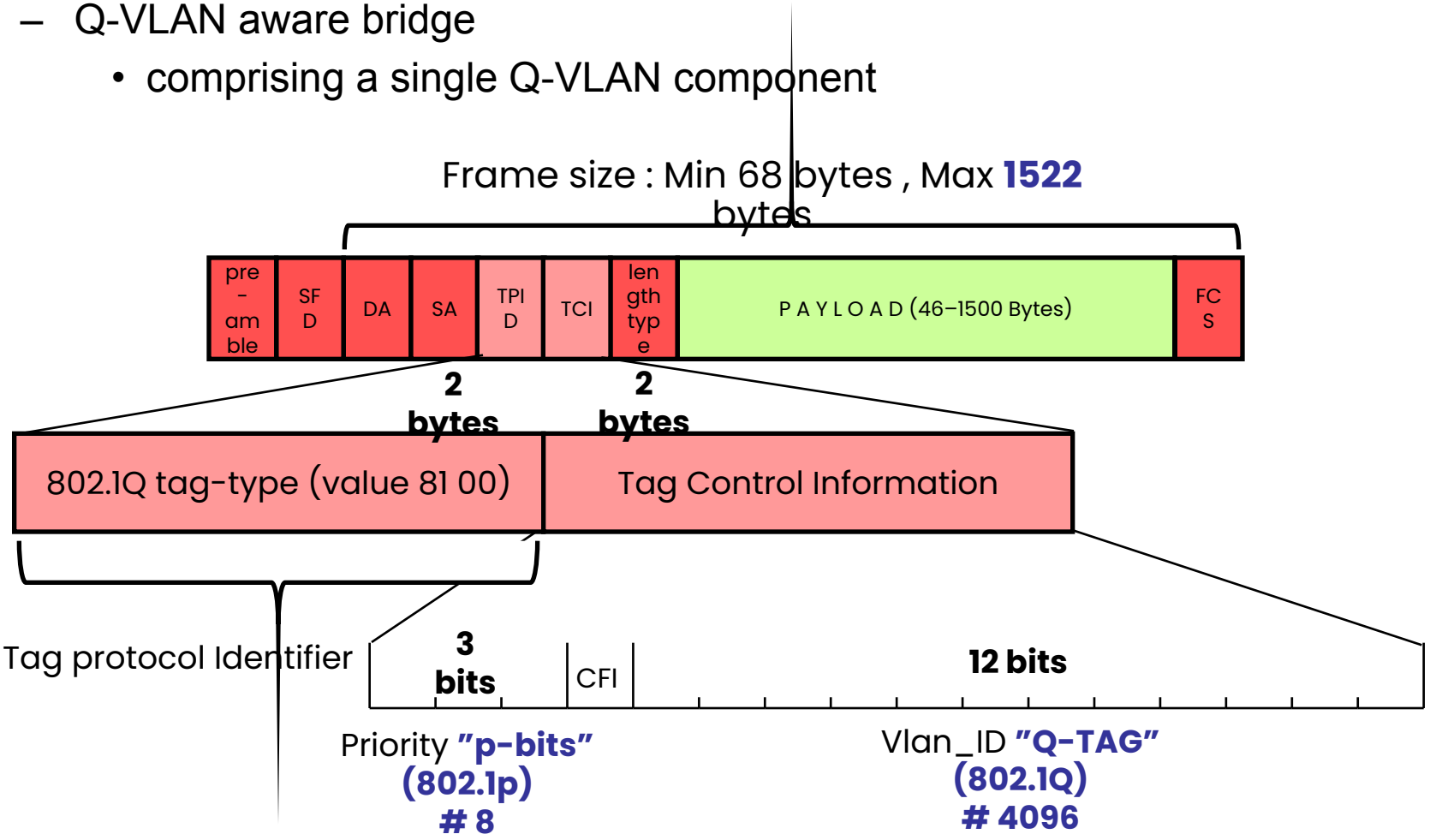
Формат кадра Q-VLAN tag (IEEE 802.1Q)

- Also referred to as C-VLAN tag
  - Customer VLAN tag
- VLAN Bridge
  - Q-VLAN aware bridge
    - comprising a single Q-VLAN component



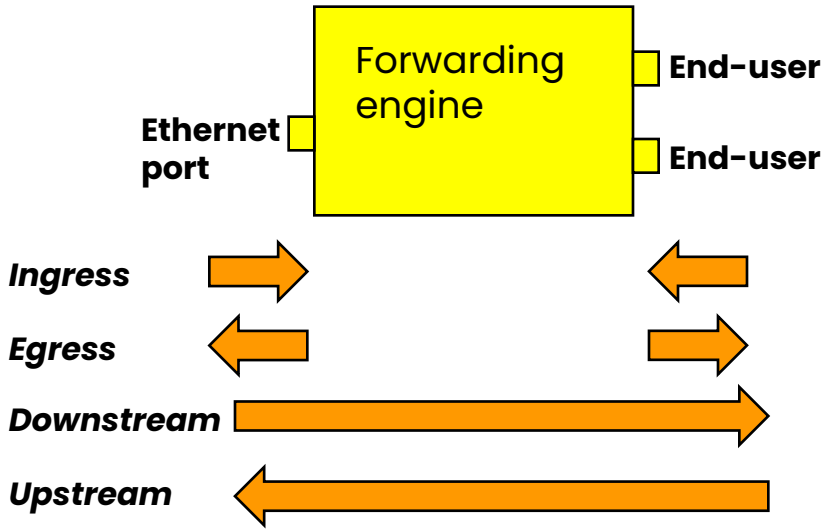
Формат кадра Q-VLAN tag (IEEE 802.1Q)

- Also referred to as C-VLAN tag
  - Customer VLAN tag
- VLAN Bridge
  - Q-VLAN aware bridge
    - comprising a single Q-VLAN component



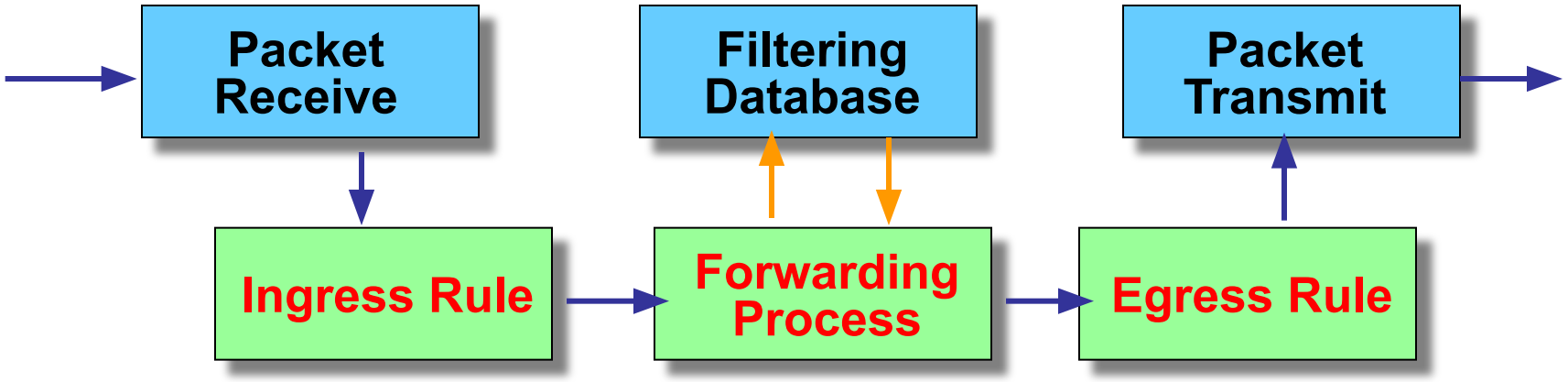
Базовые понятия процесса пересылки

- Ingress
  - Towards the forwarding Engine
- Egress
  - Out of the forwarding engine
- Upstream
  - From user to network
- Downstream
  - From network to user



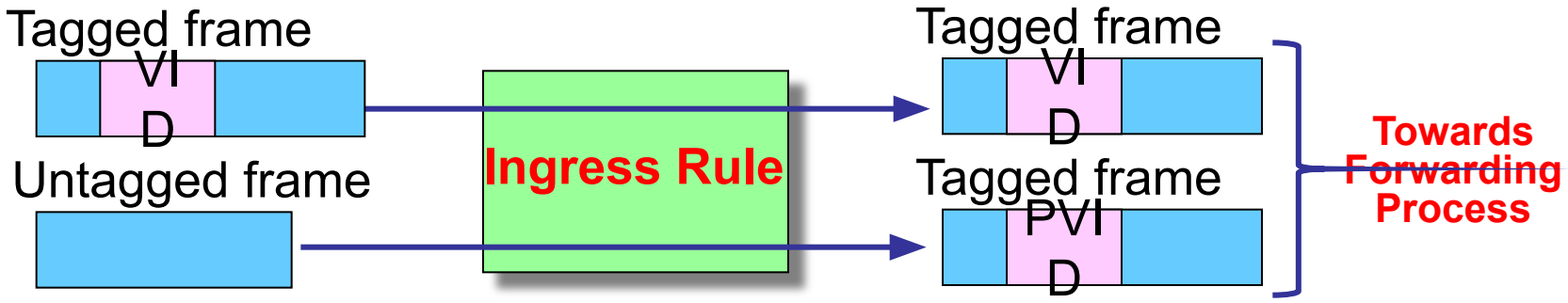
Процесс пересылки по 802.1Q

- Ingress Rule
  - Classify the received frames belonging to a VLAN
- Forwarding Process
  - Decide to filter or forward the frame
- Egress Rule
  - Decide if the frames must be sent tagged or untagged



Правила входа

- VLAN-aware switch can accept tagged and untagged frames
- Tagged frame:
  - is directly sent to the forwarding engine
- Untagged frame:
  - A tag is added onto this untagged frame (with the PVID)
  - Then the tagged frame is sent to the forwarding engine
- PVID
  - Default Port VLAN ID for incoming untagged frames



Процесс пересылки

- Forwarding decision is based on the filtering database
  - Filtering database contains two tables.
    - - MAC table and VLAN table
  - First, check destination MAC address based on the MAC table
  - Second, check the VLAN ID based on the VLAN table
- Egress port is the allowed outgoing member port of VLAN

Filtering Database

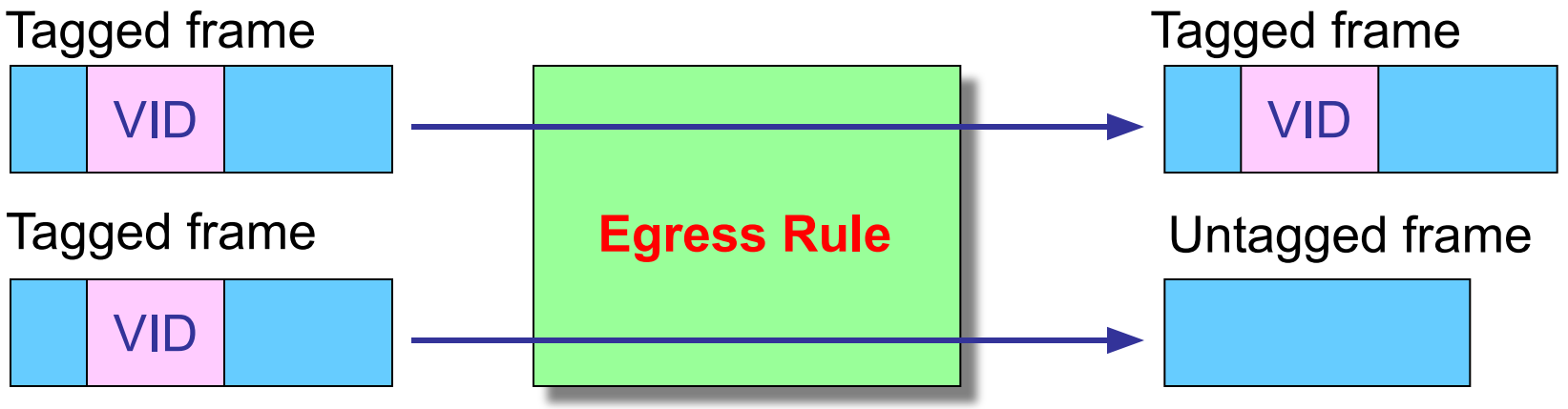
MAC Table

Port	MAC Address	Aging
2	00:A0:C5:11:11:11	0
2	00:A0:C5:22:22:22	20
3	00:A0:C5:33:33:33	30
10	00:A0:C5:44:44:44	100

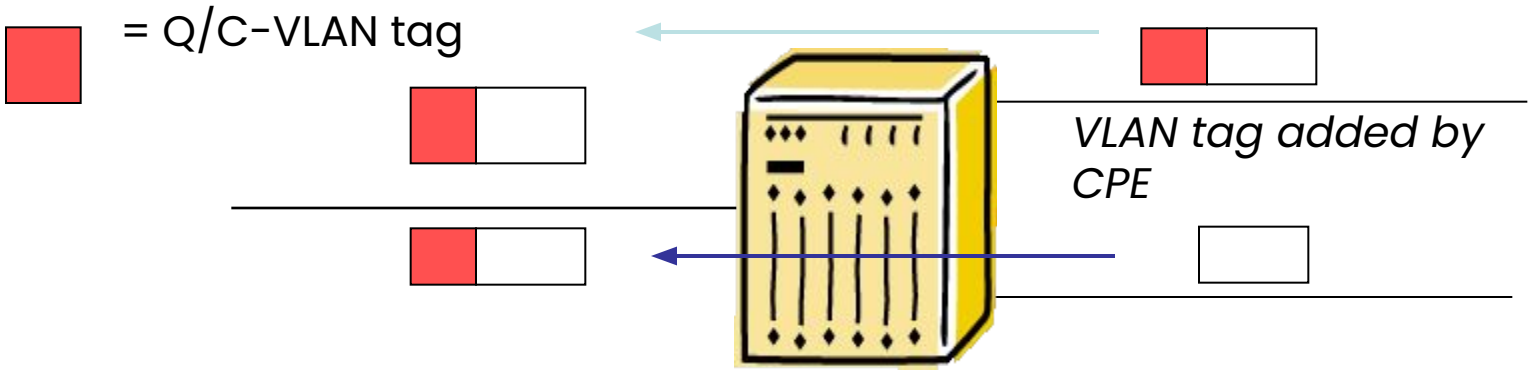
VLAN Table

VID	Egress Port	Register	Egress frame type
1	2	Static	Untag
1	3	Static	Tag
100	3	Static	Untag

Правила выхода

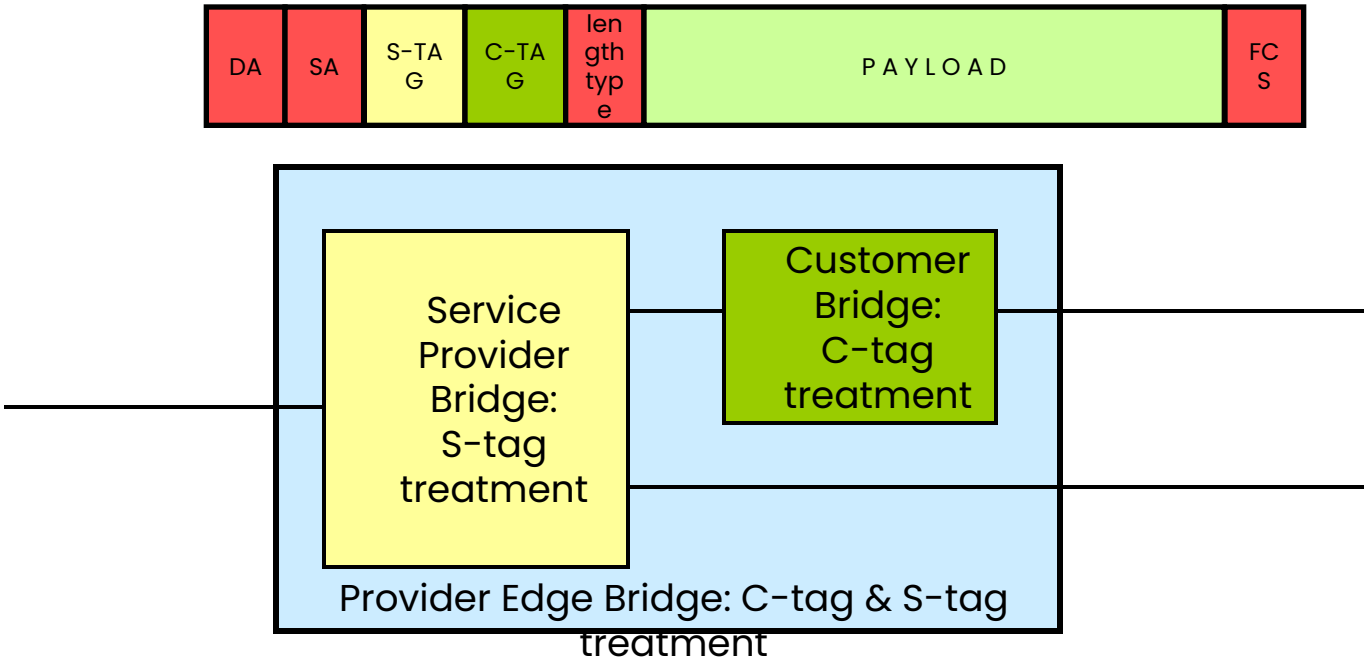


Работа коммутатора с одной меткой



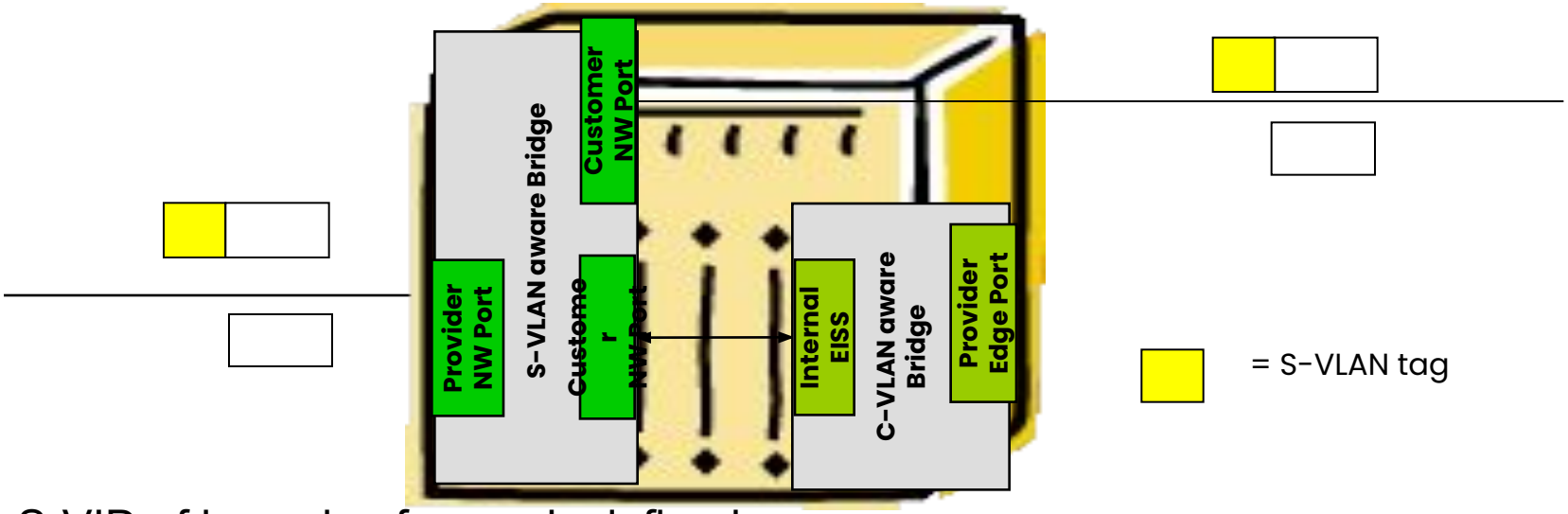
- C-VID of incoming frames is determined:
  - If TAG is present, C-VLAN ID is taken from tag (no translation!)
  - If TAG is not present,
    - * port and protocol are used for VLAN ID classification.
    - * else, the default VLAN ID for that port is used (PVID);
- Outgoing frame may carry C-TAG or not, depending on egress rule.

Структура коммутатора для стека меток



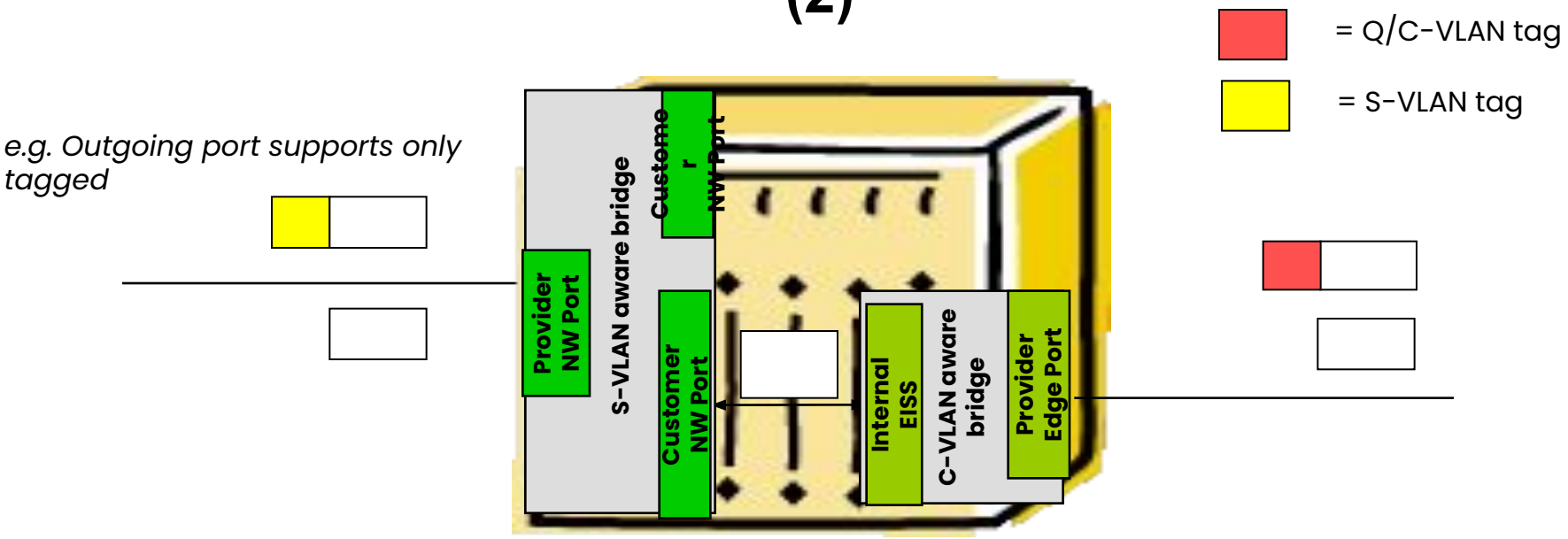
- Single VLAN tag:
  - Only 4094 VIDs ⇨ Scalability issue
- Inroduction of second VLAN tag (IEEE 802.1ad):
  - Servider Provider tag: S-TAG

Коммутатор провайдерского класса с одной меткой (1)



- S-VID of incoming frames is defined:
  - If S-TAG is present, S-VID is taken from tag
  - If S-TAG is not present,
    - Same rules as for C-TAG in VLAN bridge.
- Incoming frame is forwarded according to forwarding information base associated with the S-VLAN.
- Outgoing frame may carry S-TAG or not (egress rule).

Коммутатор провайдерского класса с одной меткой (2)

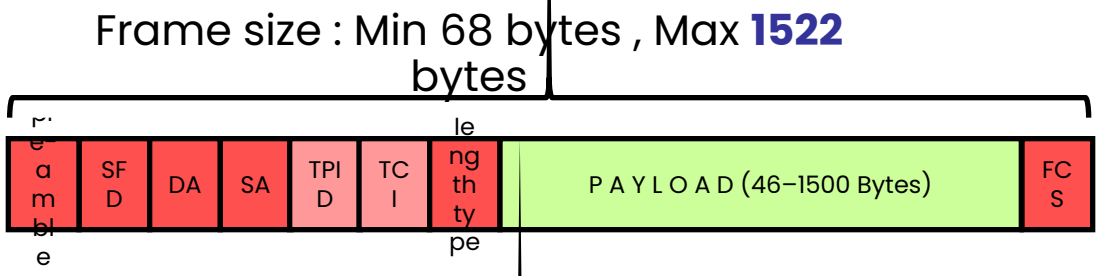


- An incoming frame on a provider edge port is forwarded internally depending on the C-TAG.
  This two-step approach enables a **translation** of C-VID to S-VID.
- Incoming frame is forwarded according to forwarding information base associated with respectively the C-VLAN / S-VLAN to which the frame belongs.
- Outgoing frame may carry S-TAG or not (egress rule)

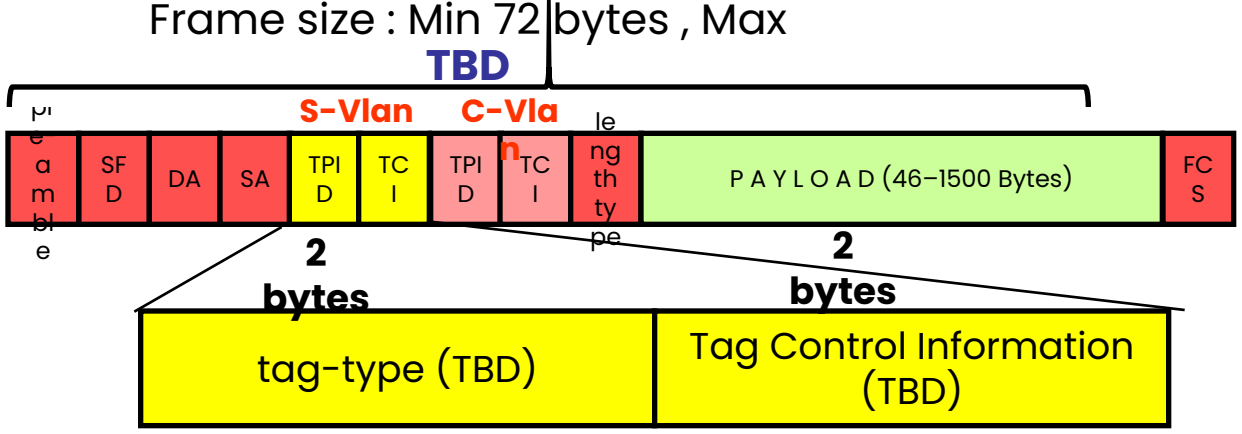
Стекирование VLAN

- IEEE 802.1ad
  - Certain vendors apply today 1Q-in-Q VLAN Tag
    - like Alcatel,…

Single VLAN tag



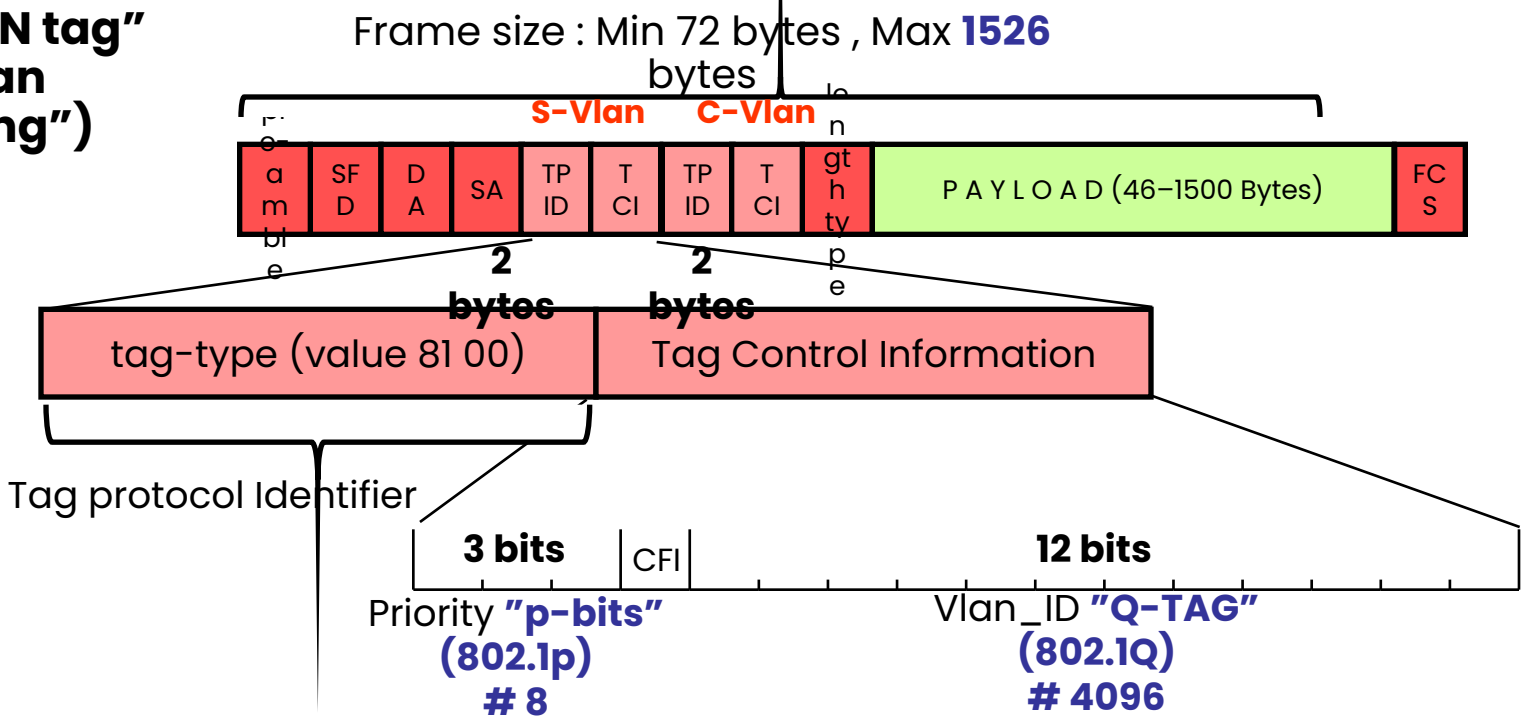
Dual VLAN tag" ("Vlan stacking")



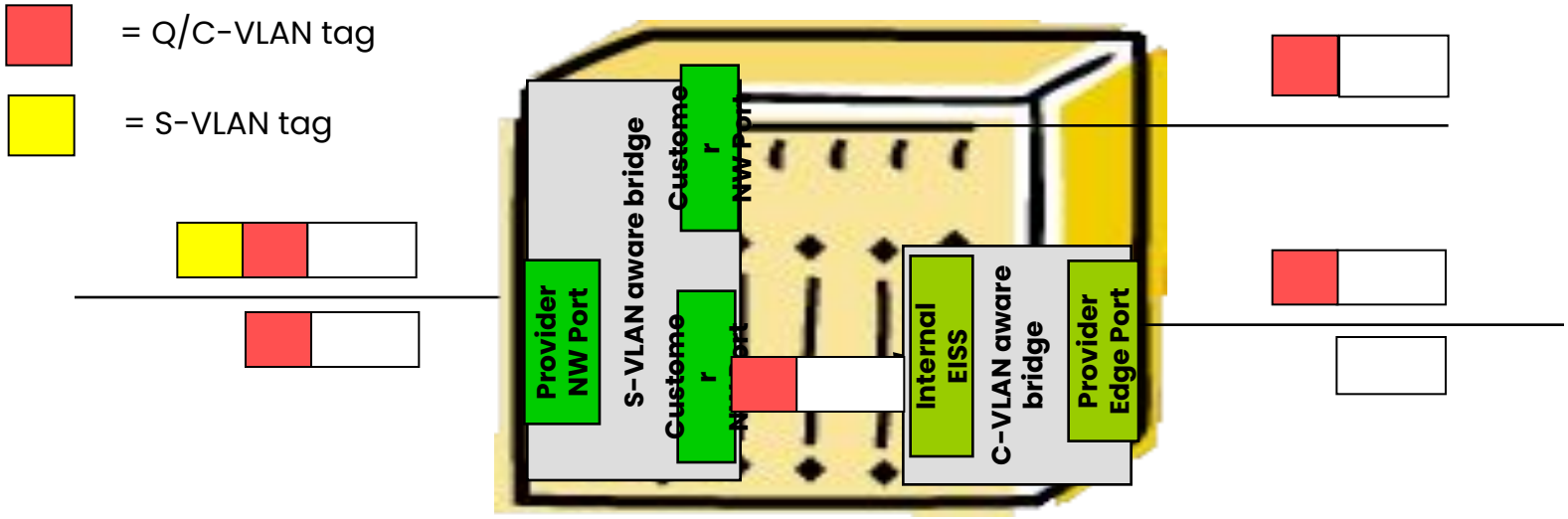
Формат S-метки

- Q-in-Q VLAN
  - Not standardized
  - The second VLAN tag protocol identifier is 802.1Q tag type just like in Single VLAN tagged frames

Dual VLAN tag" ("Vlan stacking")

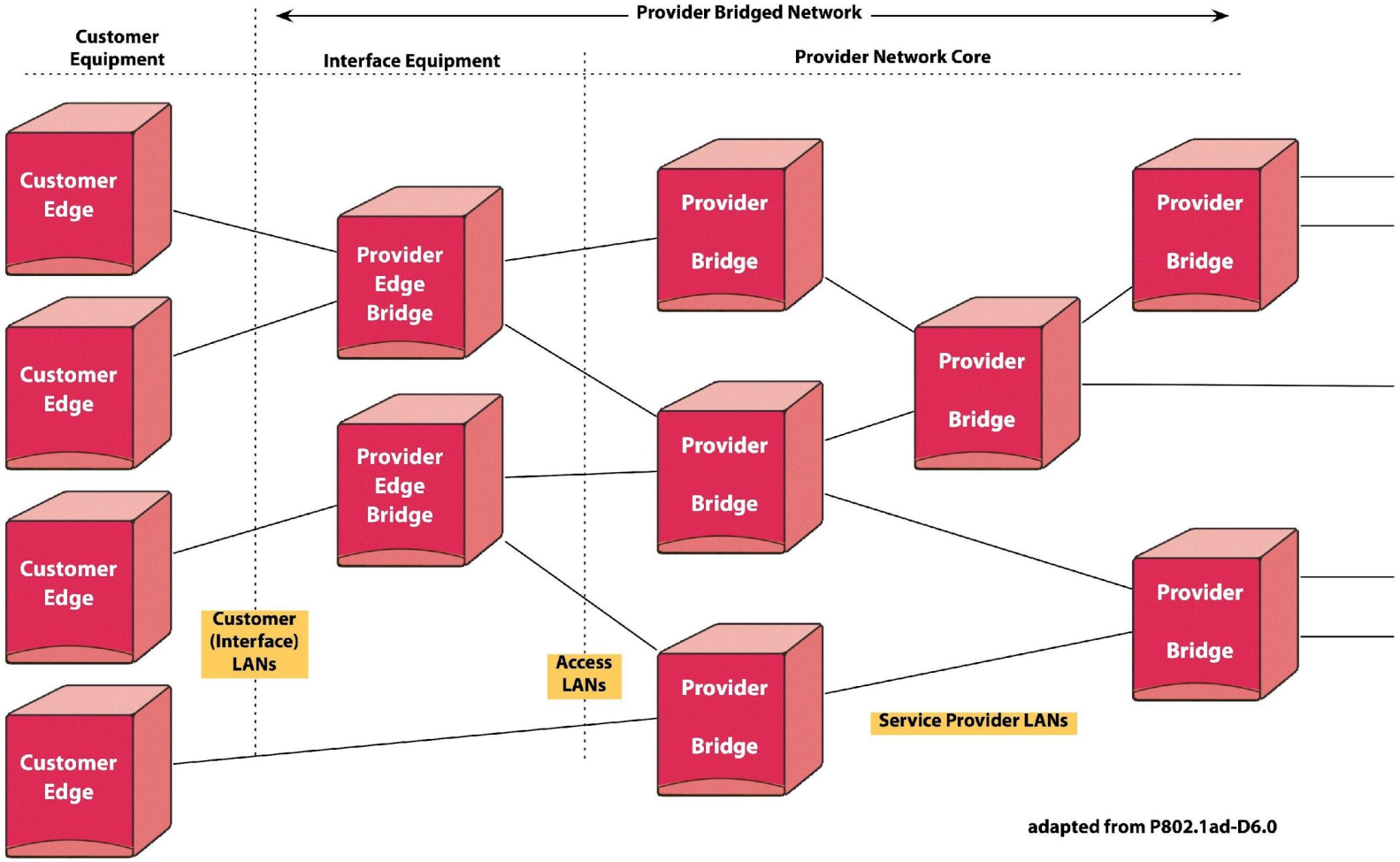


Коммутатор провайдерского класса с двумя метками



- We now have two tags
  - The S-TAG may be added and removed independently of the C-tag.
- A Provider Bridge ignores C-tags, except on Provider Edge Ports
- VLAN-stacking can occur even if the incoming frame is untagged (at provider edge port).

Структура сети METRO Ethernet



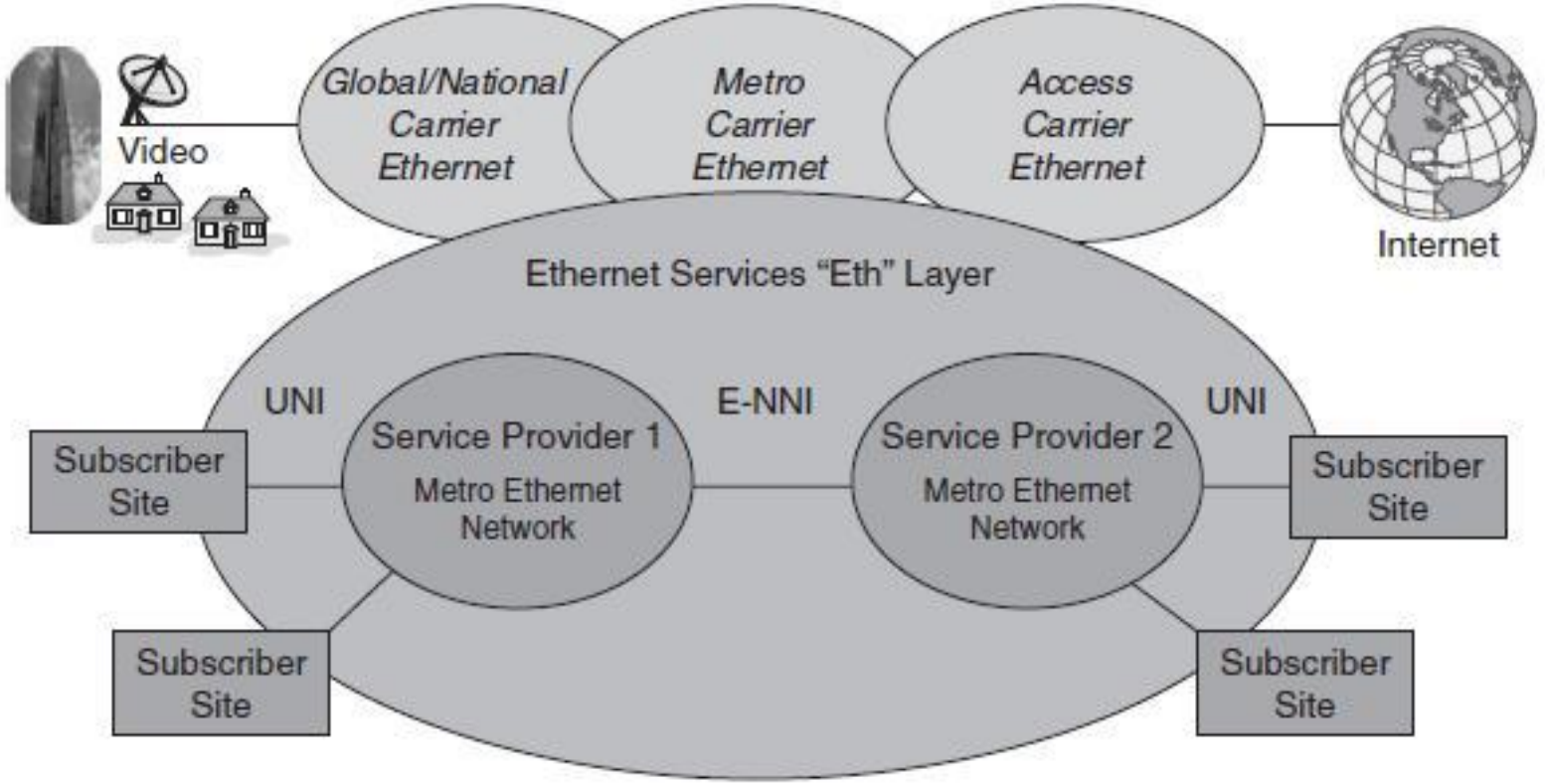
Two types of Provider Bridges.

- Provider Edge Bridge includes a component that can switch on C-VLANs
- Provider Bridge can encapsulate C-VLANs but cannot switch on them.

Сравнительная характеристика LAN и MAN сетей

Dimension	Local Area Network	Service Provider Network
Geography/Reach	Usually less than 1–2 km; deployed in building(s) and small campuses	10–100 km and longer; deployed in a metro area or even across distant metro areas
Service Provider	Enterprise (IT group); implemented by internal IT group.	Service Provider (Carrier typically); services offered commercially for an initial and recurring cost
User of service	Enterprise	Enterprise
Number of end users/points (Scale)	In the tens/hundreds	Thousands or tens/hundreds of thousands
Bandwidth	10M/100M/1000M	1M and greater—up to 10,000M; usually in granular increments of 1MAggregation required
Services offered (scope)	Enterprise data applications	Voice/TDM and data connectivity applications such as Internet Access, intra-metro connectivity
Delivery of Ethernet services	Over coax (CAT 5) and fiber; Best effort	Over a host of media, incumbent transport technologies, and with an associated service-level agreement (SLA)
Tolerance to failures (resiliency)	Generally reasonable because network is usually intra-enterprise and over a smaller physical area so failures can be addressed relatively quickly	Very low tolerance because failures usually have a larger impact—often on revenues and competitiveness
Manageability	Manageability possible with fairly simple tools given fewer number of users and applications within a smaller physical area (typically a building or campus) and the relatively higher tolerance to failure issues	Scale and scope of the Service Provider network in terms of the number of users and the geographical footprint introduces significant complexity necessitating sophisticated

Структура Carrier Ethernet



Определение

- **Carrier Ethernet: A Formal Definition**

  The MEF1 has defined Carrier Ethernet as the "ubiquitous, standardized, Carrier-class service defined by five attributes that distinguish Carrier Ethernet from the familiar LAN based Ethernet." These five attributes, in no particular order, are

  1. Standardized services
  2. Scalability
  3. Reliability
  4. Quality of Service (QoS)
  5. Service management OAM

Стандартизация Carrier Ethernet

Ethernet Standards Summary

Standards Body	Ethernet Services	Architecture/Control	Ethernet OAM	Ethernet Interfaces
IEEE	-	• 802.3 – MAC • 802.3ar – Congestion Management • 802.1D/Q – Bridges/VLAN • 802.17 - RPR • 802.1ad – Provider Bridges • .1ah – Provider Backbone Bridges (PBB) • .1ak – Multiple Registration Protocol • .1aj – Two Port MAC Relay • .1AE/af – MAC / Key Security • .1aq – Shortest Path Bridging • .1Qay – PBB – Traffic Engineering	• 802.3ah – EFM OAM • 802.1ag – CFM • 802.1AB - Discovery • 802.1ap – VLAN MIB	• 802.3 – PHYs • 802.3as - Frame Expansion
MEF	• MEF 10 – Service Attributes • MEF 3 – Circuit Emulation • MEF 6 – Service Definition • MEF 8 – PDH Emulation • MEF 9 – Test Suites • MEF 14 – Test Suites • Services Phase 2	• MEF 4 – Generic Architecture • MEF 2 – Protection Req & Framework • MEF 11 – UNI Req & Framework • MEF 12 - Layer Architecture	• MEF 7– EMS-NMS Info Model • MEF 15– NE Management Req • OAM Req & Framework • OAM Protocol – Phase 1 • Performance Monitoring	• MEF 13 - UNI Type 1 • MEF 16 – ELMI • E-NNI
ITU	• G.8011 – Services Framework • G.8011.1 – EPL Service • G.8011.2 – EVPL Service • G.asm – Service Mgmt Arch • G.smc – Service Mgmt Chnl	• G.8010 – Layer Architecture • G.8021 – Equipment Model • G.8010v2 – Layer Architecture • G.8021v2 – Equipment Model • Y.17ethmpls - ETH-MPLS Interwork	• Y.1730 – Ethernet OAM Req • Y.1731 – OAM Mechanisms • G.8031 – Protection • Y.17ethqos – QoS • Y.ethperf - Performance	• G.8012 – UNI/ NNI • G.8012v2 – UNI/ NNI
TMF	-	-	• TMF814 – EMS to NMS Model	-

Общие требования к сервисам

■ **Ubiquity** Carrier Ethernet enables ubiquitous Ethernet services provided via standardized equipment, independent of the underlying media and transport infrastructure. This is a critical prerequisite to extending Ethernet's appeal globally (similar to LAN Ethernet)

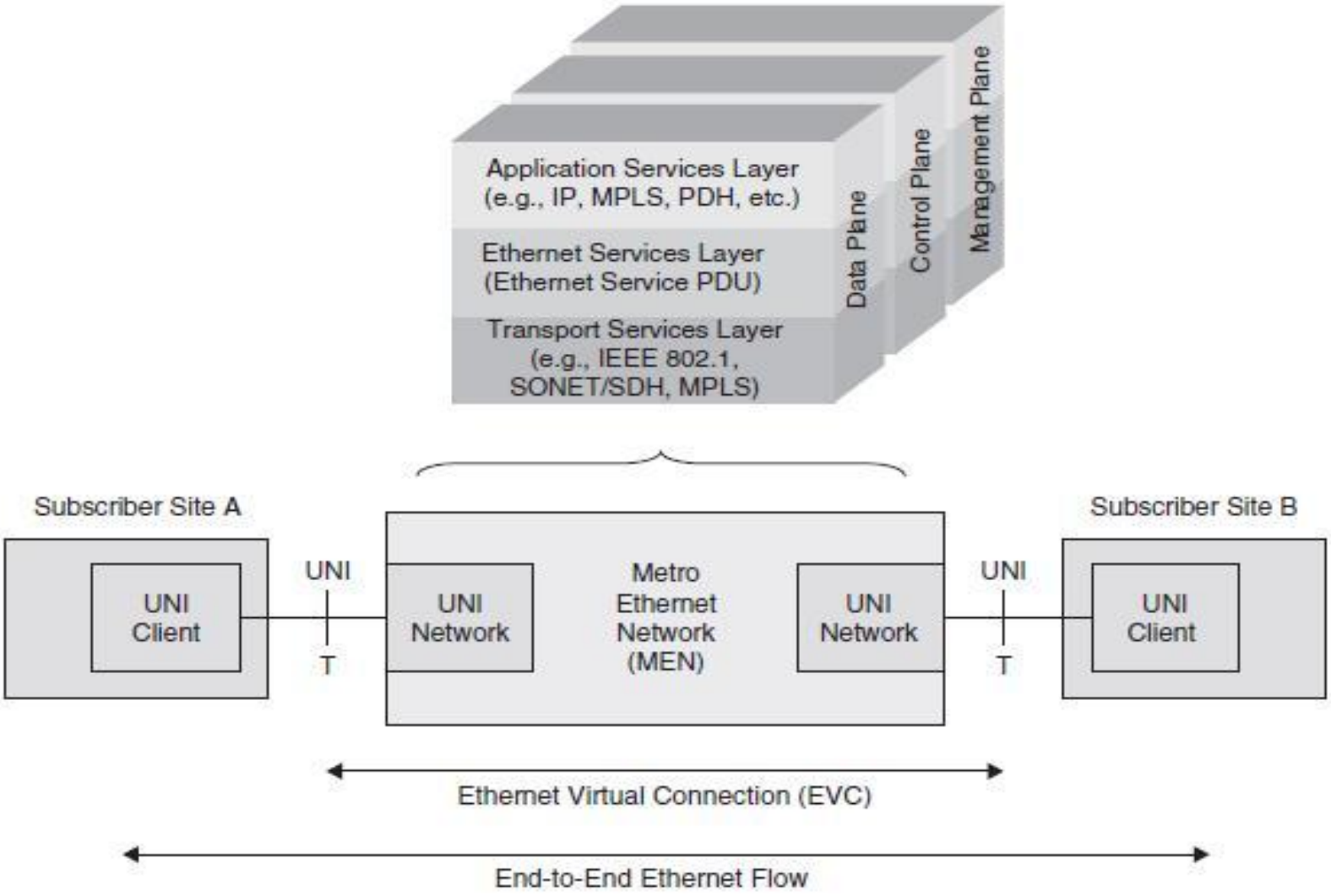
.■ **Ethernet Services** Carrier Ethernet supports two types of services: Point-to-Point (also referred to as Ethernet Line or E-LINE) and multipoint-to-multipoint Ethernet LAN (referred to as E-LAN) Ethernet services. These services are discussed in greater detail later in the chapter and are expected to provide the basis for all Ethernet services.

■ **Circuit Emulation Services (CES)** Carrier Ethernet supports not only Ethernet-based services delivered across different transport technologies but also other (TDM) services transported over Carrier Ethernet itself. As noted previously, TDM services still remain an overwhelming contributor to Service Provider revenues and realistically need to be supported (and delivered over a converged Ethernet-based infrastructure). TDM-based voice applications especially need to be accommodated and characteristics of such applications such as synchronization and signaling need to be emulated.

■ **Granularity and Quality of Services (QoS)** The services supported by Carrier Ethernet provide a wide choice and granularity of bandwidth and quality of service options. This flexibility is vital in Service Provider networks with its multitude of end users, each with slightly different application requirements and, typically, operating equipment from multiple vendors. QoS capability is crucial to enforcing the deterministic behavior of Carrier Ethernet.

■ **Converged transport** Supports convergence of voice, data, and video services over a unified (Ethernet) transport and greatly simplifies the delivery, management, and addition of such services. Basically, all enterprise services and applications are now supported over a single Ethernet "pipe".

Модель Ethernet сервисов



Типы Ethernet сервисов

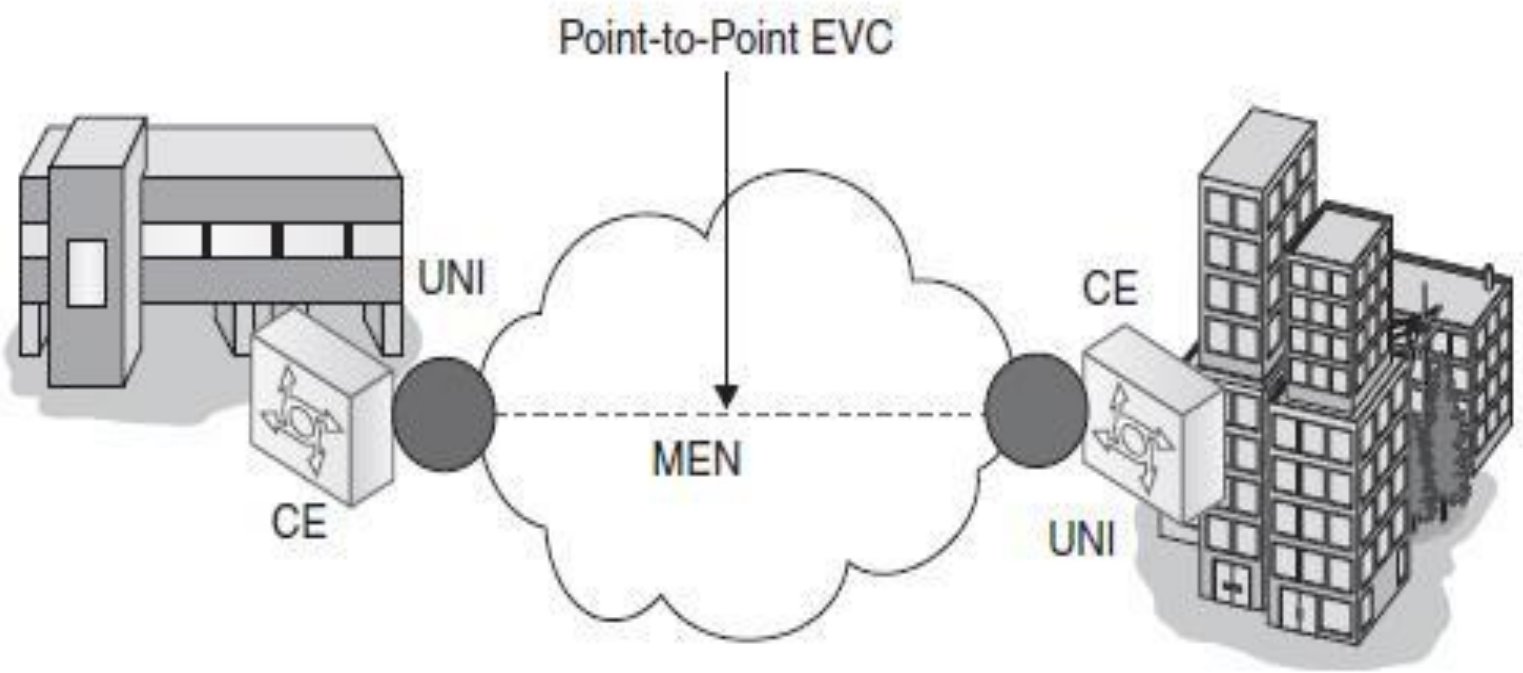
- **Ethernet Service Types**

  The Ethernet service type is essentially a generic Ethernet connectivity construct. The MEF has defined two basic service types:

  - Ethernet Line (E-LINE)
  - Ethernet LAN (E-LAN)
  - Ethernet Tree (E-Tree)

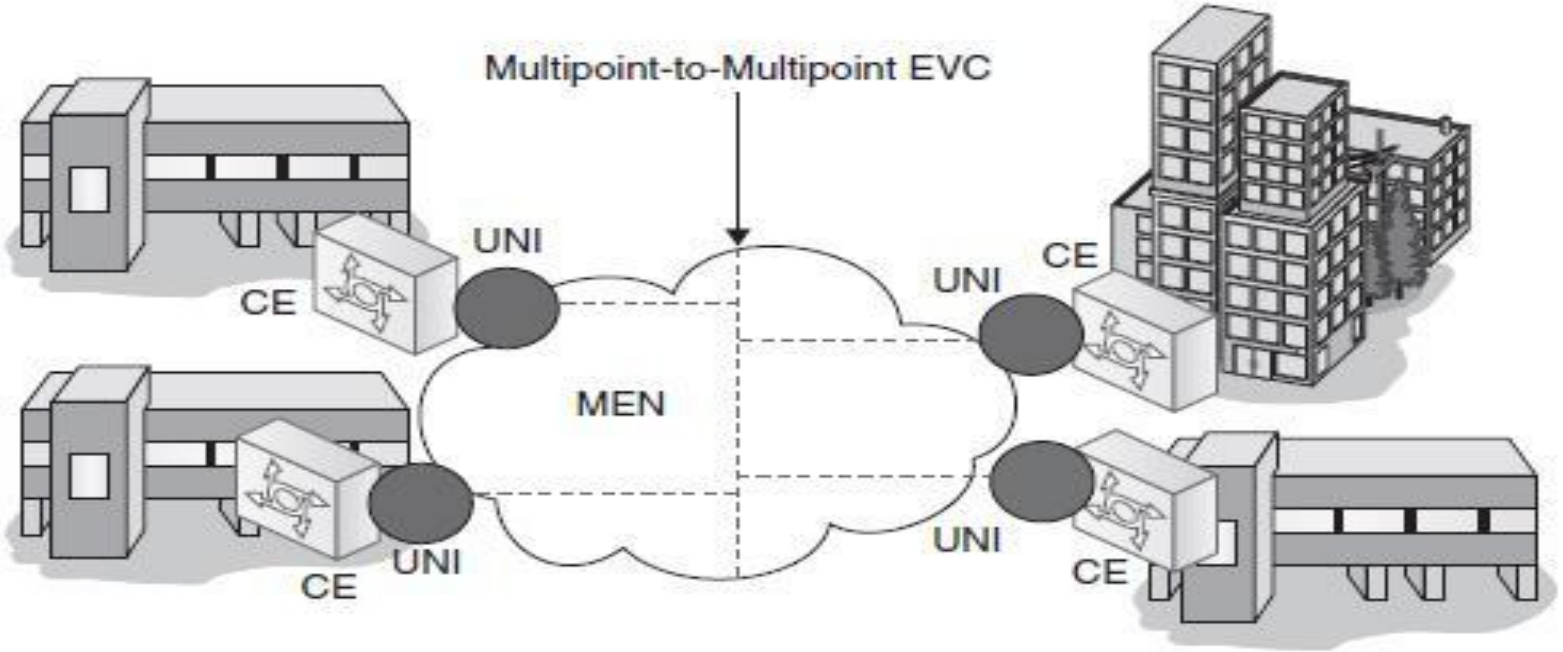
Сервис E-Line

- **Ethernet Line (E-LINE) Service** Any Ethernet service that is based on a Point-to-point Ethernet Virtual Connection (EVC) is designated as an Ethernet Line (E-LINE) service type. An E-LINE service type can be used to create a broad range of Point-to-Point Ethernet services between two UNIs.

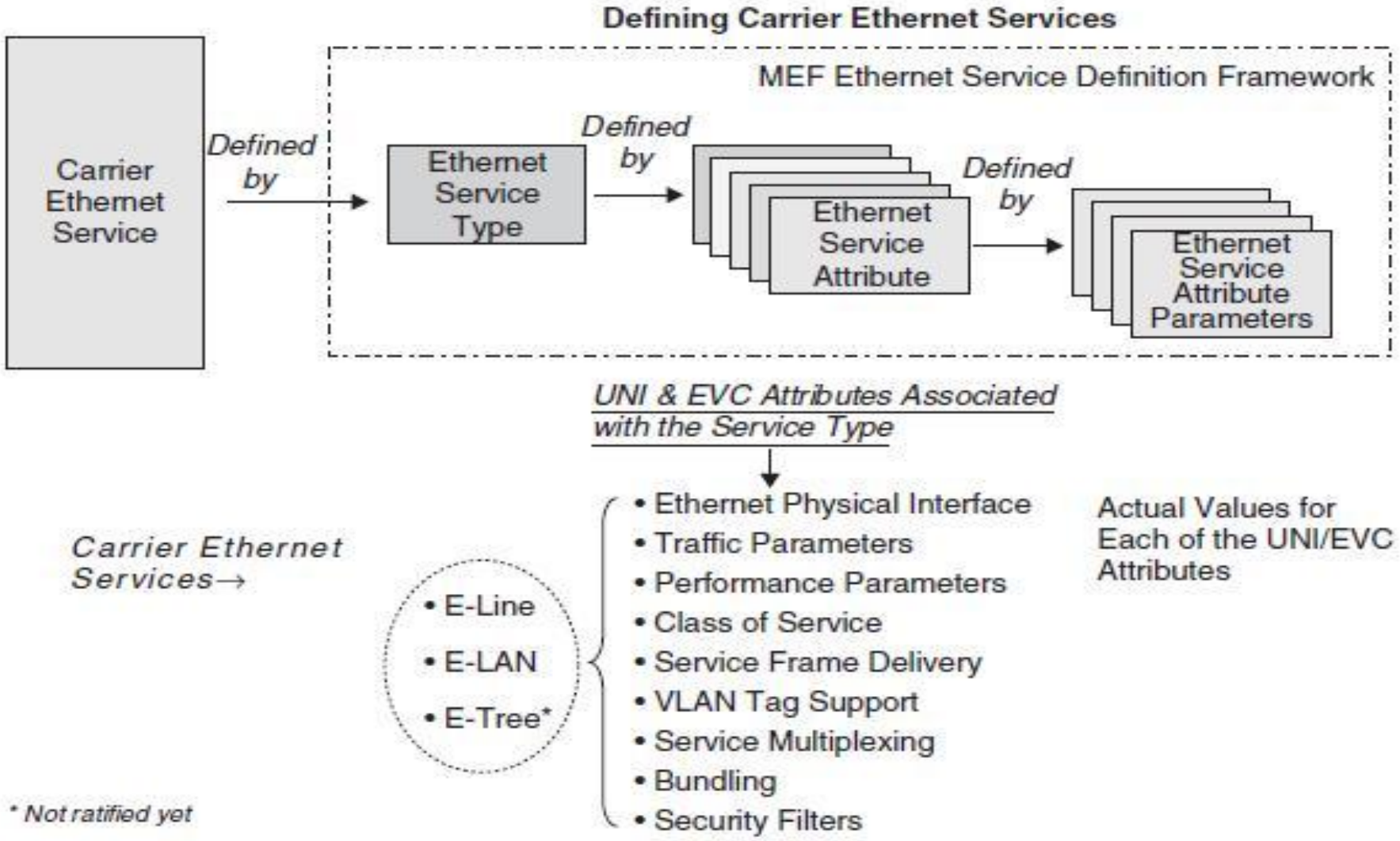


Сервис E-LAN

- **Ethernet LAN (E-LAN) Service** Any Ethernet service that is based upon a Multipoint-to-Multipoint Ethernet Virtual Connection (EVC) is designated as an Ethernet LAN (E-LAN) service type. An E-LAN service connects two or more UNIs and service frames sent from one can be received at one or more of the other UNIs. In an E-LAN service, each UNI is connected to a multipoint EVC (even an E-LAN service connected to two UNIs is comprised of a multipoint EVC and hence, not an E-LINE service, which has a Point-to-Point



Определение характеристик Ethernet сервисов



Параметры UNI

Ethernet Physical Interface. At the UNI, the Ethernet physical interface has several service attributes

Physical Medium. This UNI service attribute specifies the physical interface defined by the IEEE 802.3-2000 standard. Examples are 10BaseT, 100BaseSX, 1000BaseLX, and so on.

Speed. This UNI service attribute specifies the standard Ethernet speed—either 10 Mbps, 100 Mbps, 1 Gbps, or 10 Gbps.

Mode. This UNI service attribute specifies whether the UNI supports full or half duplex and can provide auto-negotiation.

MAC Layer. This UNI service attribute specifies which MAC layer is supported, i.e., as specified in the IEEE 802.3-2002.

Параметры трафика и полосы пропускания (1)

- **Bandwidth Profile Traffic Parameters.** A Bandwidth profile associated with an Ethernet service consists of four traffic parameters: Committed Information Rate (CIR), Committed Burst Size (CBS), Excess Information Rate (EIR), and Excess Burst Size (EBS); in addition a service frame is associated with a Color Mode (CM). Together, these five parameters specify the bandwidth profile for a particular service:
- **Bandwidth Profile = <CIR, CBS, EIR, EBS, CM>**

  Committed Information Rate (CIR). CIR is the average rate up to which service frames are delivered as per the performance objectives (such as delay, loss, etc.) associated with the service; these service frames are referred to as being CIR-conformant.The CIR value is always less than or equal to the UNI speed and basically guarantees that the specified amount of bandwidth (or service frames) will be delivered according to a predetermined performance level. A CIR of zero indicates the service has neither bandwidth nor performance guarantees.

- **NOTE** Independent of the CIR, the service frames are always sent at UNI speed.

Параметры трафика и полосы пропускания (2)

- **Committed Burst Size (CBS).** CBS is the limit on the maximum number, or bursts, of service frames in bytes allowed for incoming service frames so they are still CIR-conformant.
- **Excess Information Rate (EIR).** The EIR specifies the average rate, greater or equal to the CIR, up to which service frames are admitted into the Service Provider network; these frames are said to be EIR-conformant. These frames are delivered without any performance guarantees and are not CIR-conformant; however, service frames that are not EIR-conformant are discarded.
- Again, independent of the EIR, the service frames are always sent at the speed of the UNI (and hence, the EIR represents the average rate).
- **Excess Burst Size (EBS).** The EBS is the limit on the maximum number, or bursts, of service frames in bytes allowed for incoming service frames so they are still EIR-conformant

Параметры производительности

- **Performance Parameters.** The performance parameters affect the service quality experienced by the subscriber and consist of the following.
- **Availability.**This is still being formalized by the MEF but essentially attempts to indicate the availability of a service at a predefined performance SLA.
- **Frame Delay.** This critical parameter can have an impact on real-time applications such as VoIP and is defined as the maximum delay measured for a percentile of successfully delivered CIR-conformant (green) service frames over a time interval. The frame delay parameter is used in the CoS service attribute described shortly.
- **Frame Jitter.** This service attribute is also known as delay variation and is also critical in real-time applications such as VoIP or IP video. Such applications require a low and bounded delay variation to function seamlessly.
- **Frame Loss.** Frame loss is defined as the percentage of CIR-conformant (green) fames not delivered between UNIs over a measured interval. At this point, frame loss has been defined for only Point-to-Point EVCs.
- **NOTE** The impact of frame loss depends on specific higher-layer applications. Usually such applications have the ability to recover from frame loss.

Классы обслуживания

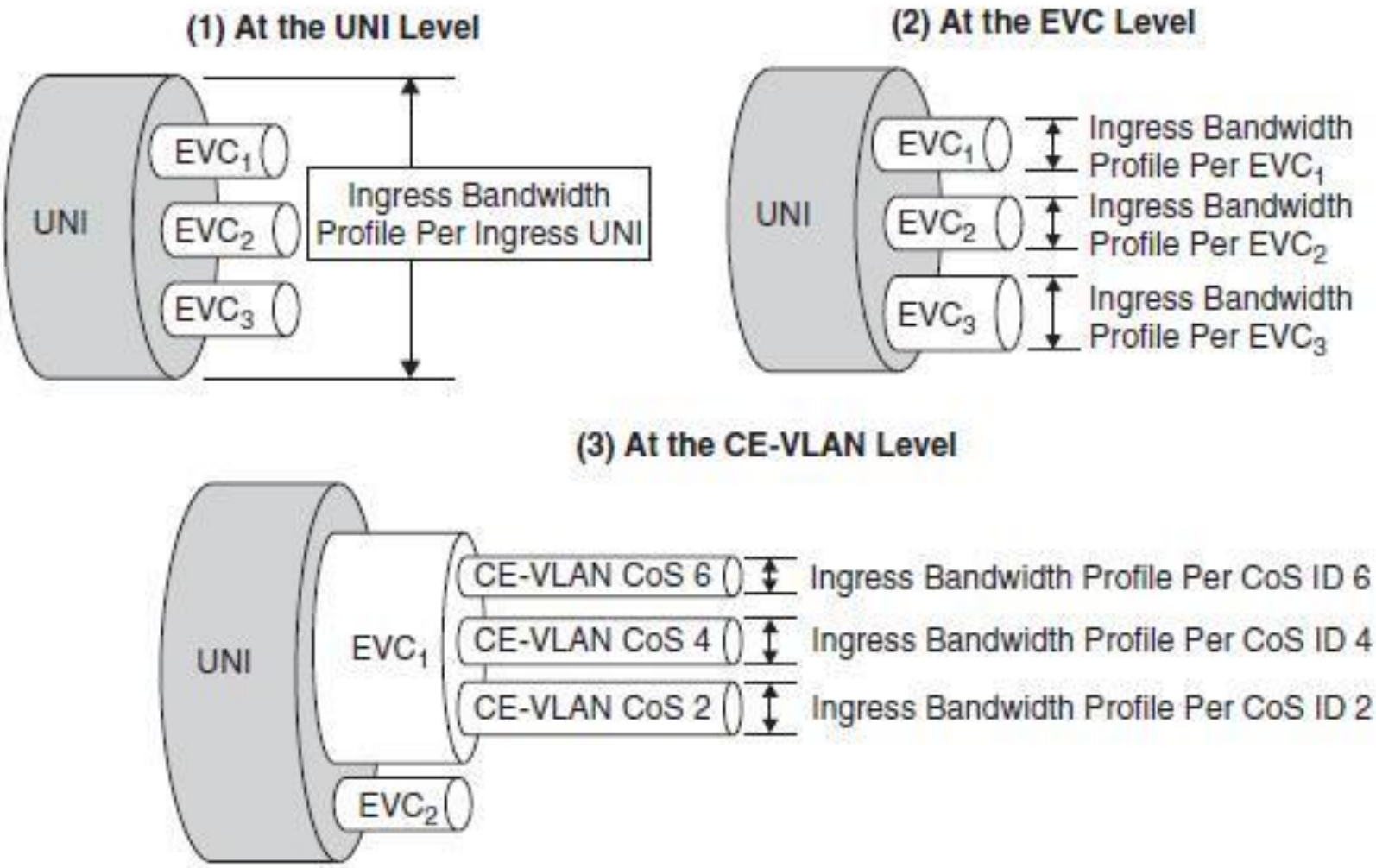
- **Class of Service (CoS)** Class of Service (CoS) refers to the performance enforced on a set of similar services. A CoS can be associated with each of the Ethernet services offered but it is usually associated with a group of services. This association becomes especially useful when there are numerous services offered over a resource (e.g., a physical port) that cannot simultaneously support all these services and also meet their respective bandwidth profiles; in such a case, a relative priority between these services becomes necessary. A CoS essentially provides this.
- The CoS is also useful because it enables Service Providers to model service demands realistically; customers are increasingly subscribing to services with very different performance demands, for example, Internet access and VoIP require different treatments.

- **Customer Equipment VLAN (CE-VLAN or 802.1p).** This CoS ID refers to the CoS (802.1p) bits in the IEEE 802.1Q tag in a tagged Ethernet service frame. These are usually referred to as the priority bits. Using this MEF-defined approach, up to eight classes of service can be provided. A bandwidth profile and performance parameters, which can be enforced by the Service Provider, are associated with each CoS. The user-defined CE-VLAN value(s) may be mapped by a service provider to its own CoS and acted on accordingly.

Типы профилей по полосе пропускания

- **Types of Bandwidth Profiles** There are three types of bandwidth profiles defined by the MEF; the initial focus has been on the ingress traffic only. Figure 2.8 illustrates the profiles.
- ■ **Ingress bandwidth profile per ingress UNI** This profile provides rate enforcement for all Service Provider frames entering the UNI from subscriber to provider networks. This is useful when only a single service is supported at the UNI, i.e., the UNI is basically considered to be a pipe. The pipe's diameter (bandwidth profile) can be controlled by varying the CIR and EIR parameters. Rate enforcement is non discriminating and some frames may get more bandwidth than others.
- ■ **Ingress bandwidth profile per EVC** This bandwidth profile provides more granular rate enforcement for all service frames entering the UNI that are associated with each EVC. This is useful when multiple services are supported at the UNI; if each EVC is considered to be a pipe inside of a larger UNI pipe, then the bandwidth profile of the EVC—or diameter of the pipe—can be controlled by varying CIR and EIR values.
- ■ **Ingress bandwidth profile per CoS (or CE-VLAN CoS)** This bandwidth profile provides rate enforcement for all service frames belonging to each CoS associated with a particular EVC. The CoS is identified via a CoS identifier determined via the <EVC, CE-VLAN CoS> pair, so that this bandwidth profile applies to frames over a specific EVC with a particular CoS value or even a set of CoS value

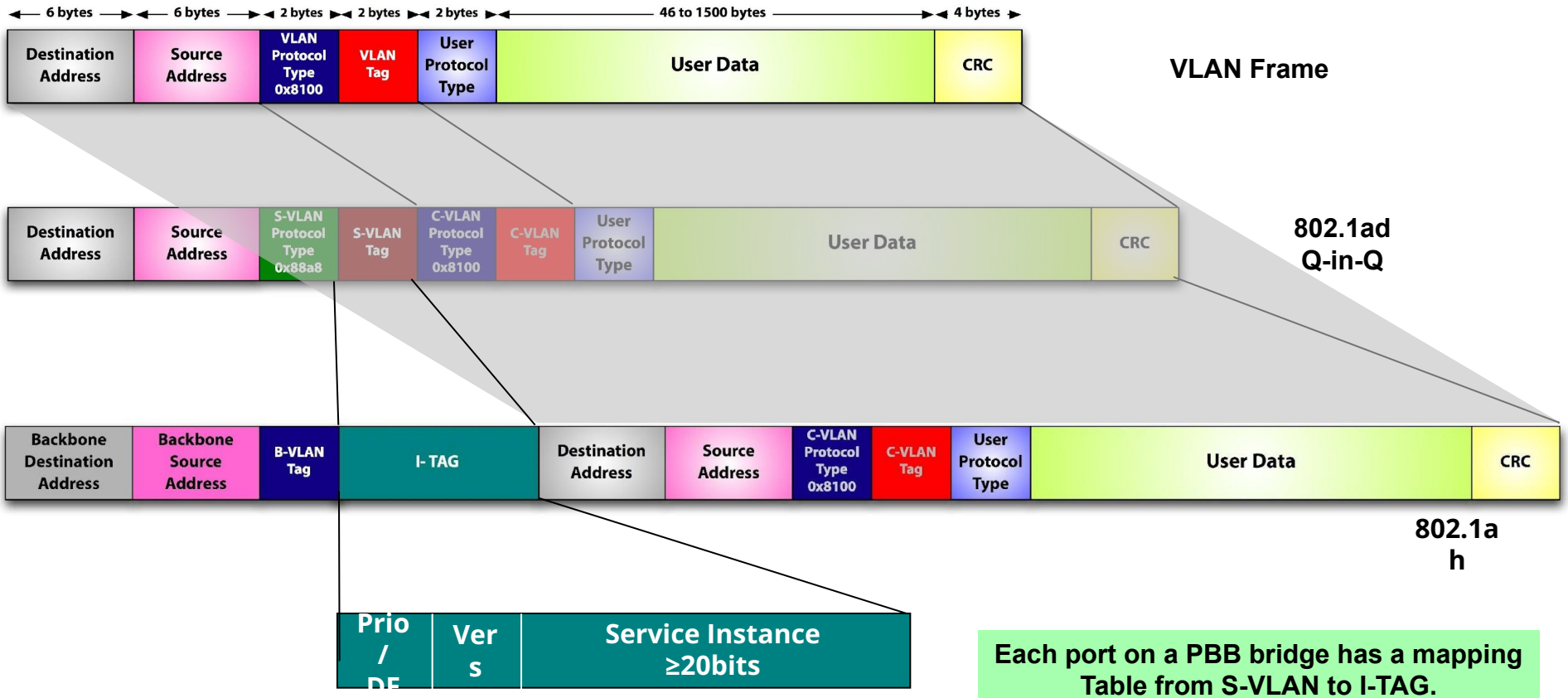
Уровни профилей по полосе пропускания



Способы расширения сетей Metro Ethernet

- **SONET/SDH-based Ethernet MANs**
- A SONETA SONET/SDH based Ethernet MAN is usually used as an intermediate step in the transition from a traditional, time-division based network, to a modern statistical network (such as Ethernet). In this model, the existing SDH infrastructure is used to transport high-speed Ethernet connections. The main advantage of this approach is the high level of reliability, achieved through the use of the native SDH protection mechanisms, which present a typical recovery time of 50 ms for severe failures. On the other hand, an SDH-based Ethernet MAN is usually more expensive, due to costs associated with the SDH equipment that is necessary for its implementation. Traffic engineering also tends to be very limited. Hybrid designs use conventional Ethernet switches at the edge of the core SDH ring to alleviate some of these issues, allowing for more control over the traffic pattern and also for a slight reduction in cost.
- **MPLS-based Ethernet MANs**
- An MPLS based Metro Ethernet network uses **MPLS** in the Service Provider's Network. The subscriber will get an Ethernet interface on Copper (ex:-100BASE-TX in the Service Provider's Network. The subscriber will get an Ethernet interface on Copper (ex:-100BASE-TX) or fiber (ex:-100BASE-FX). The customer's Ethernet packet is transported over MPLS and the service provider network uses Ethernet again as the underlying technology to transport MPLS. So, it is Ethernet over MPLS over Ethernet.

Формат кадра стандарта 802.ah



The actual format and size of the fields has not been finalized yet in the standard.

Each port on a PBB bridge has a mapping Table from S-VLAN to I-TAG.

This also allows S-VLAN translation on opposite sides of the backbone network

Полная структура мультисервисной транспортной сети