MPLS

Multi-protocol label switching

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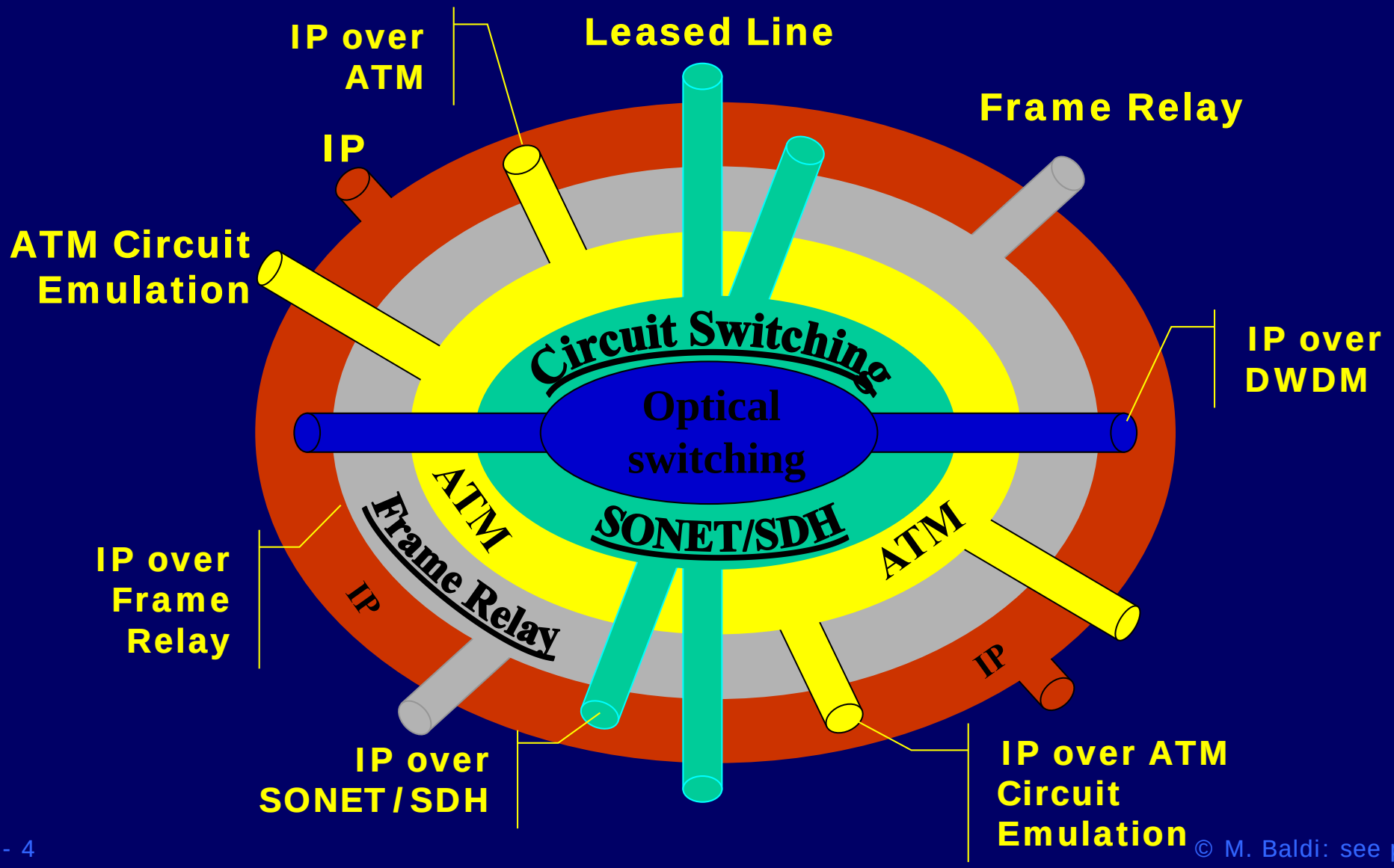
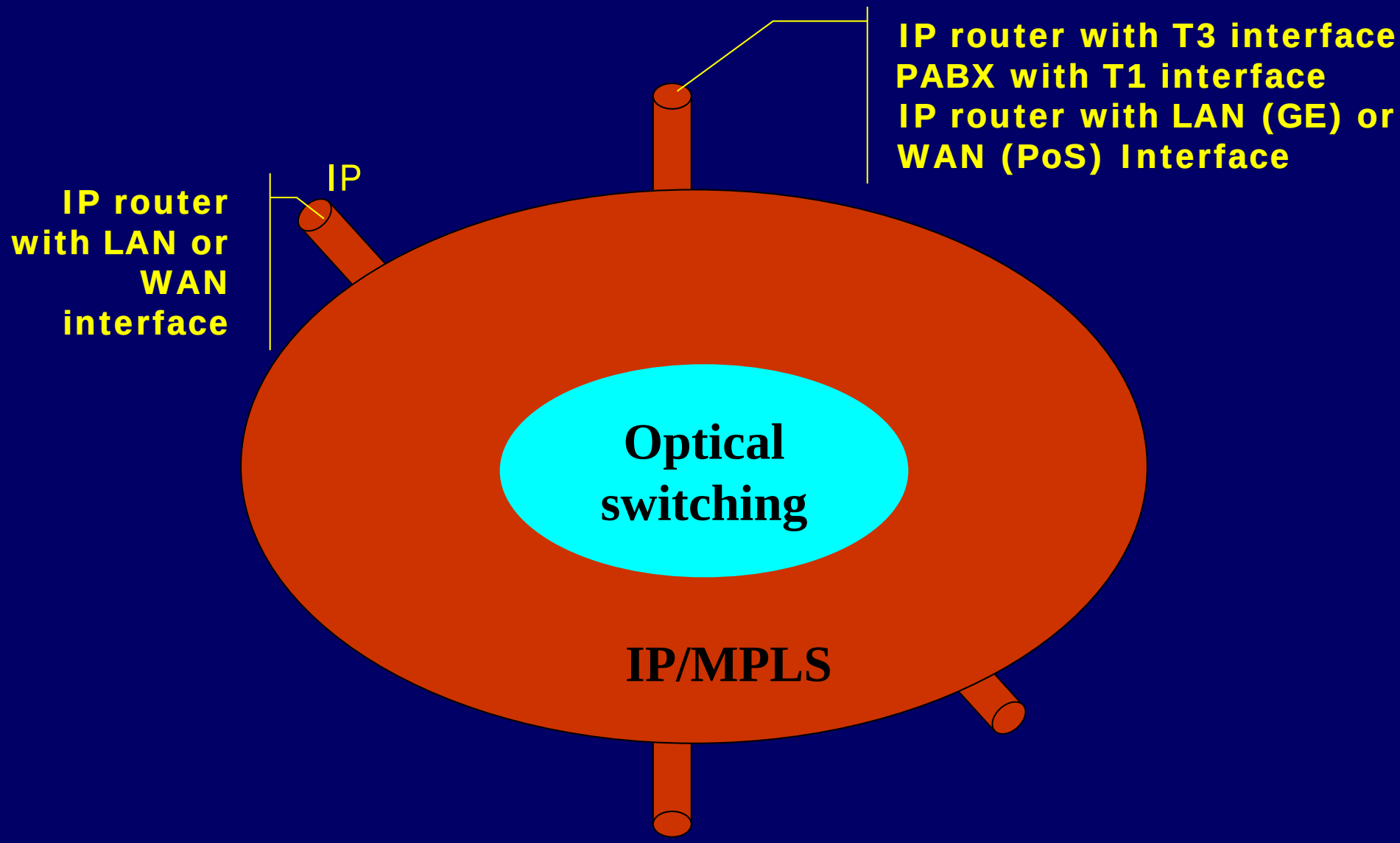
From MPLS Forum Documents

MPLS is the enabling technology for the New Broadband (IP) Public Network

The “onion” that makes telecos “cry”



The future: WDM, IP, MPLS



The idea

Forwarding packets according to a label

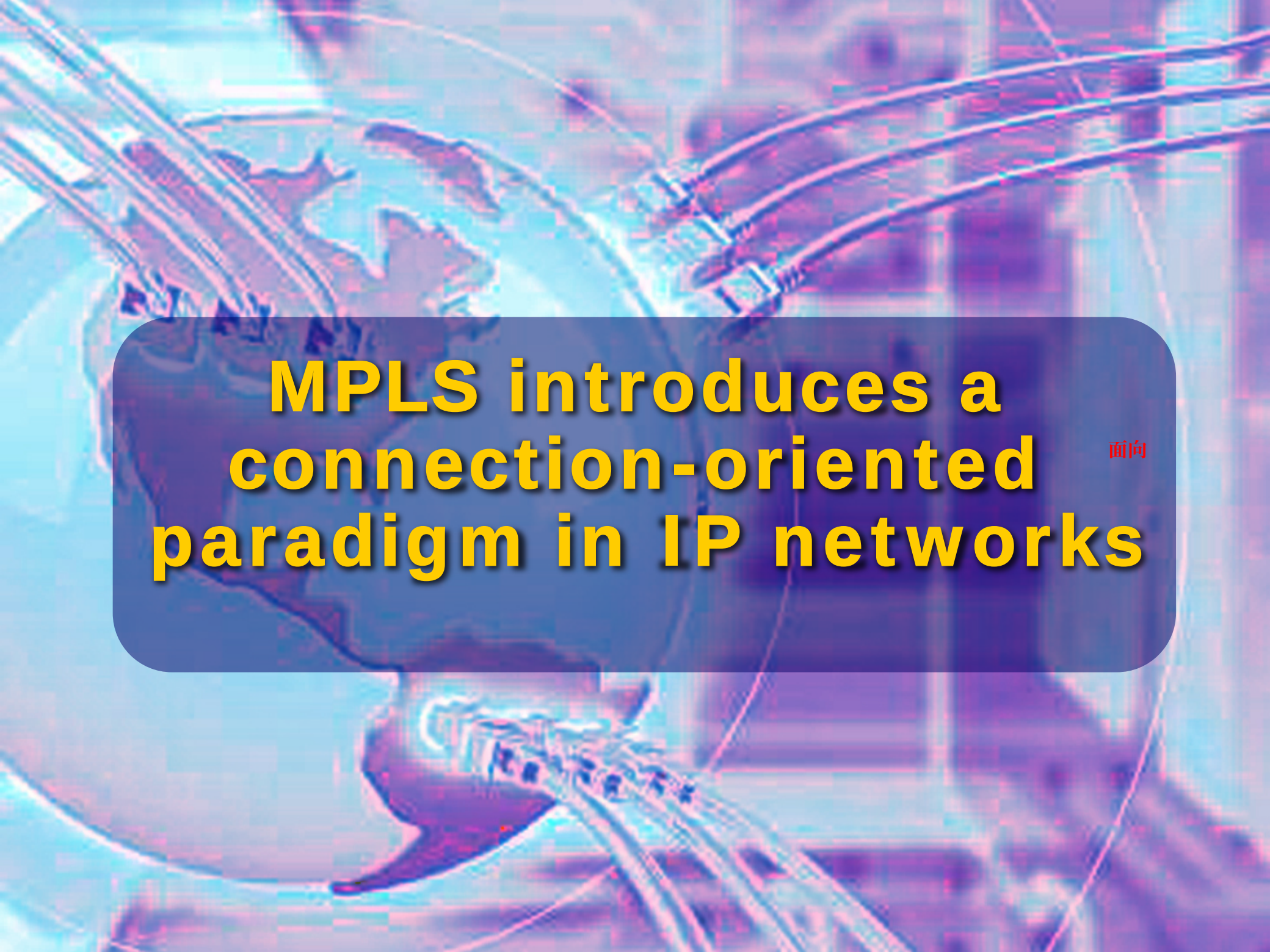
Instead of the IP destination address

Why?

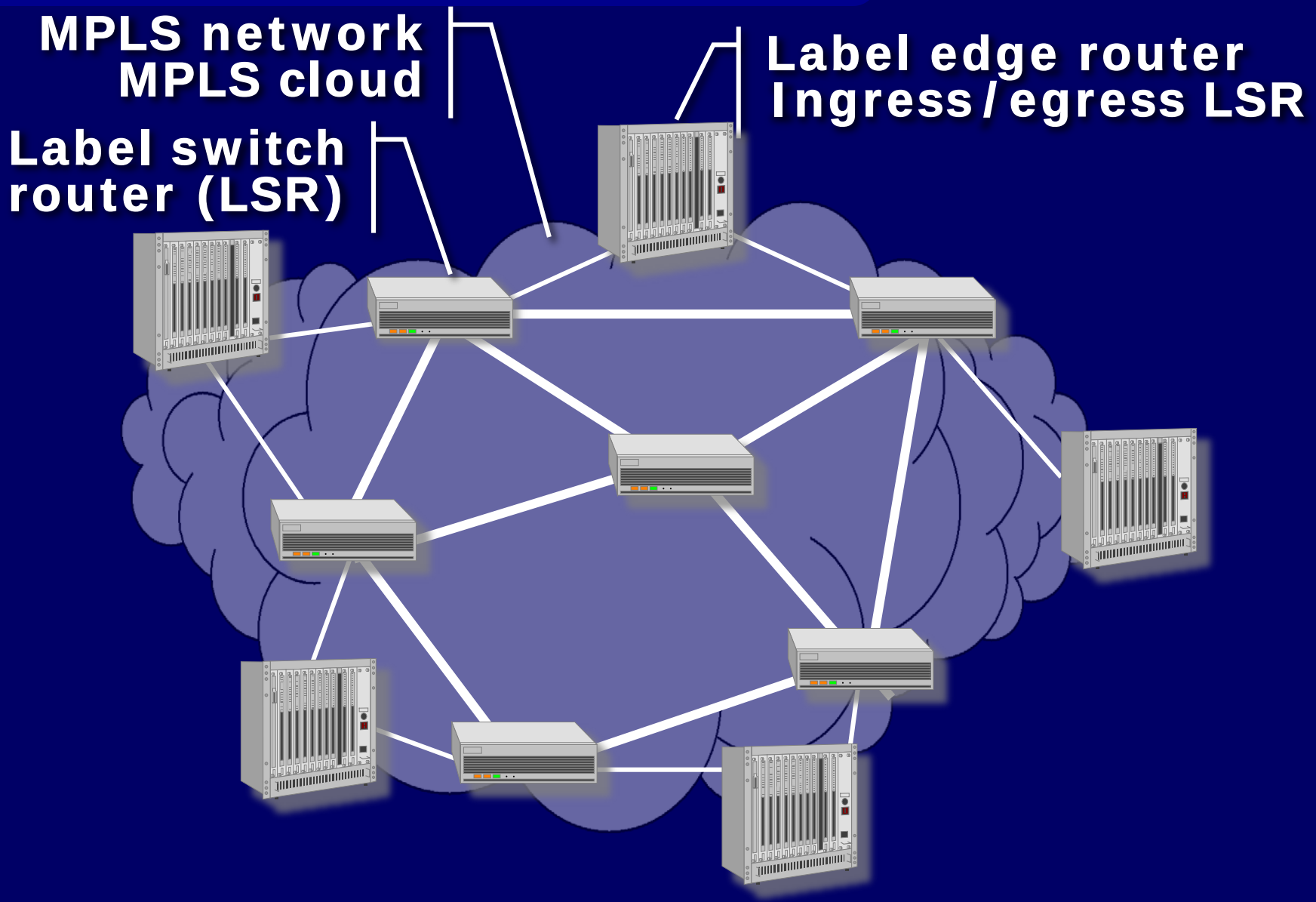
Faster lookup

- → The label may be used as an index
  - → Instead of longest prefix matching

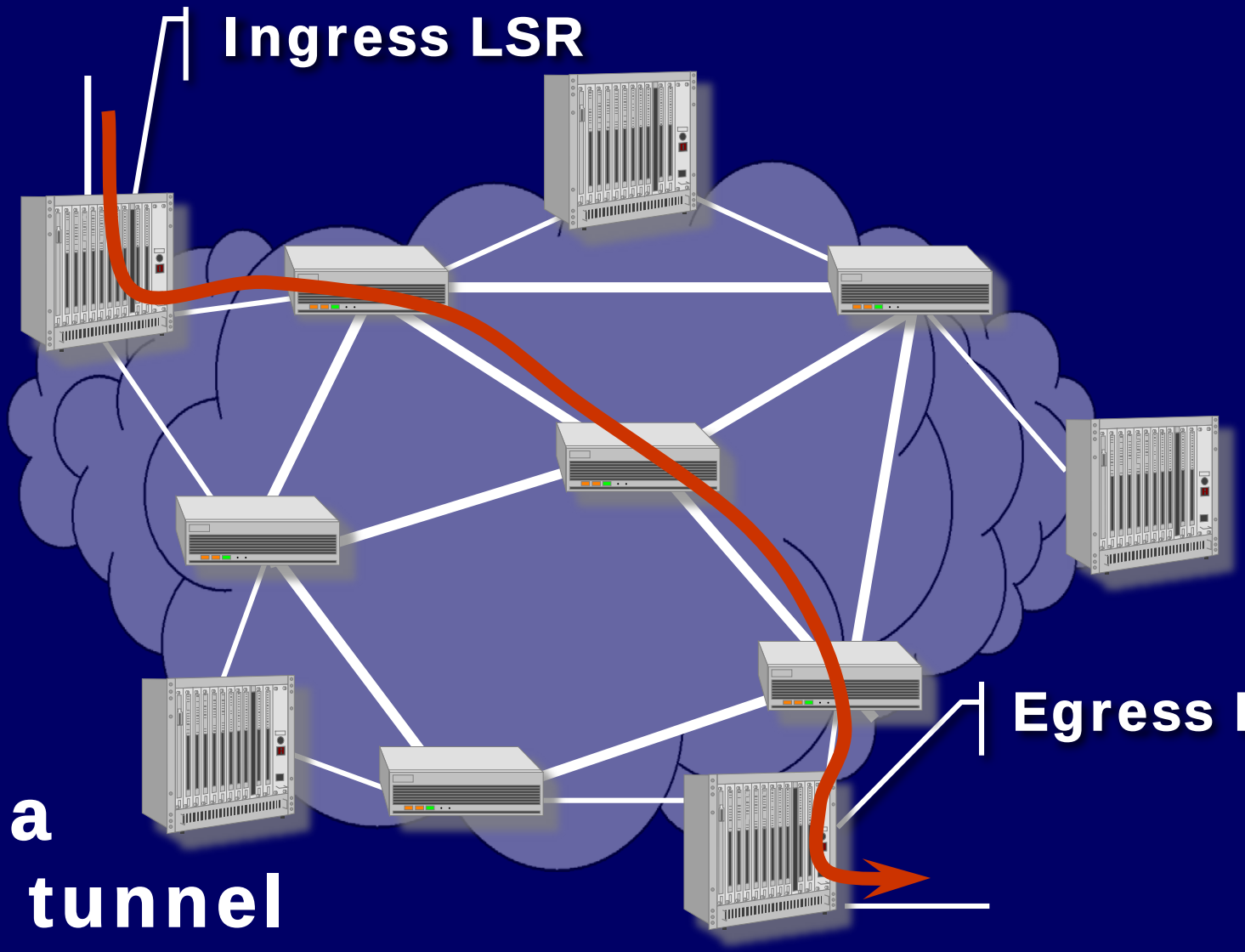
Traffic engineering


MPLS introduces a
connection-oriented
paradigm in IP networks
面向

Network architecture

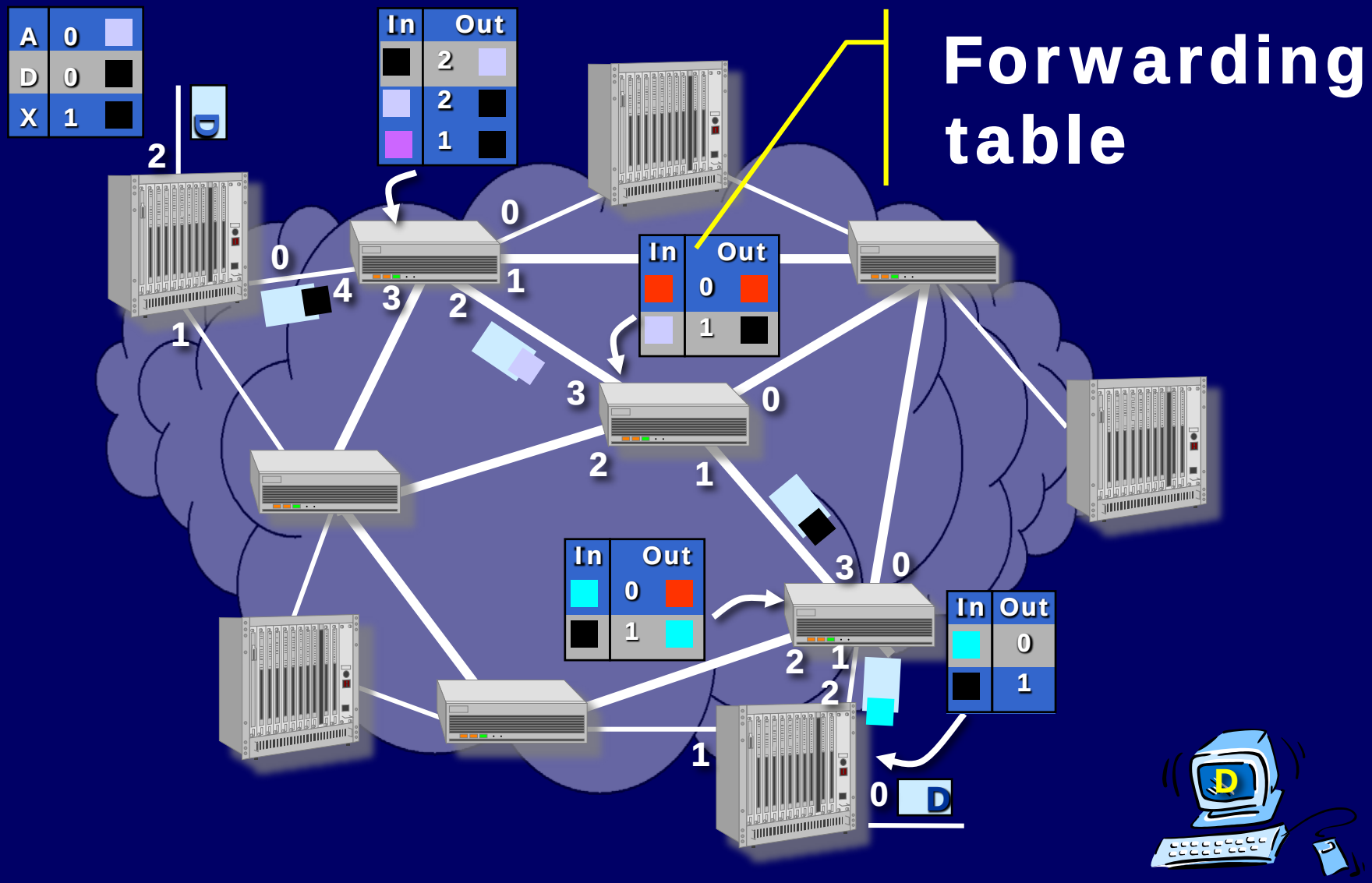


Label Switched Path (LSP)



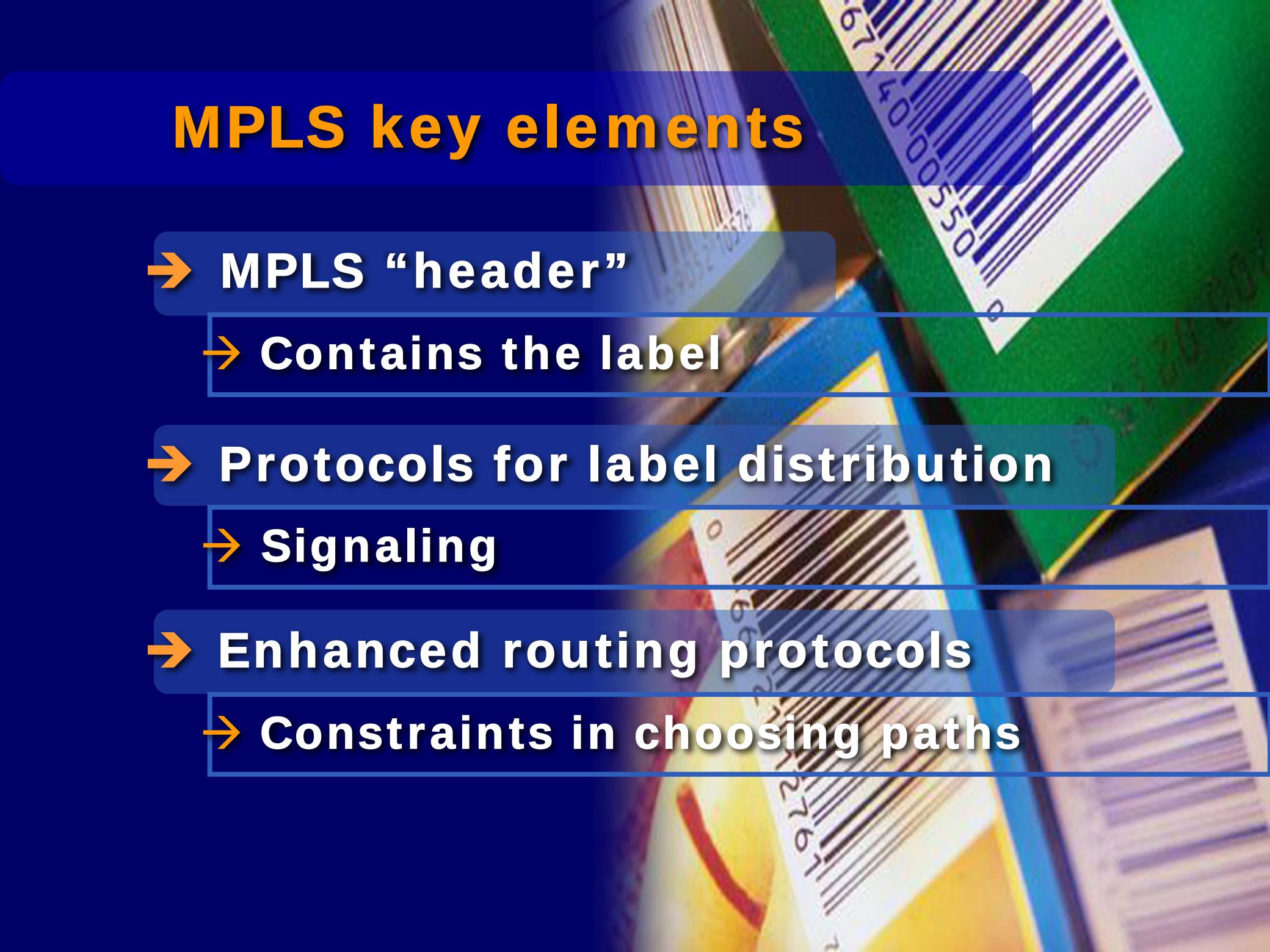
A.k.a
LSP tunnel

Label switching



MPLS key elements

- MPLS “header”
  - Contains the label
- Protocols for label distribution
  - Signaling
- Enhanced routing protocols
  - Constraints in choosing paths



MPLS history

- Tag Switching
- IP *over* ATM
  - No problems with resolution of addresses
  - Simpler signaling
  - Only one control plan
- ATM *with* IP
  - Reusing ATM switching hardware

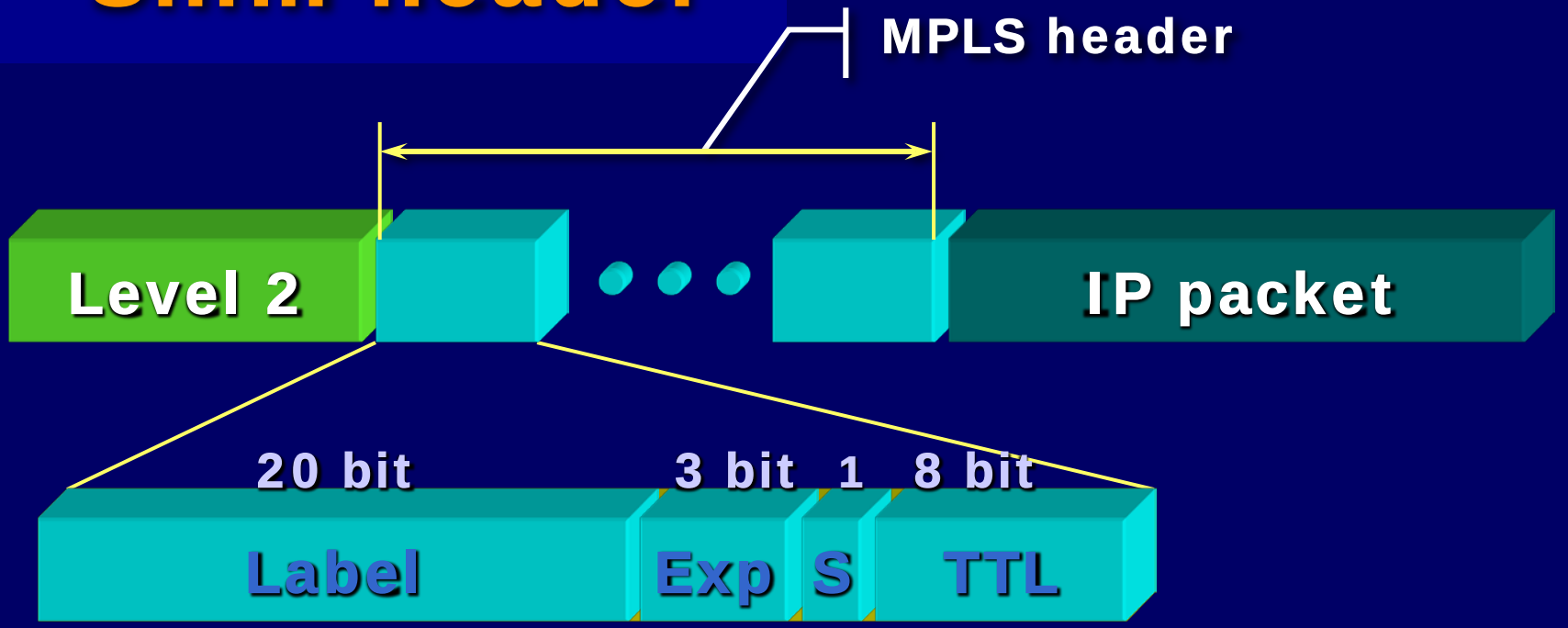
MPLS history

- MPλS (Multi-Protocol Lambda Switching)
- G-MPLS (Generalized MPLS)
  - Packet switching
  - Cell switching
  - Circuit switching (SONET/SDH)
  - Lambda switching
  - Anything switching

Unifying control plane

MPLS “header”

Shim header



Exp: Experimental bits (CoS)
S: Bottom of stack
TTL: Time to live

ATM and frame relay

ATM面向L2的协议

Connection oriented layer 2 protocols

MPLS labels in layer 2 header

- → VCI / VPI (ATM)
- → DLCI (Frame relay)

LSP setup: label and path selection

A glimpse into the control plane

Forwarding equivalence class (FEC)

Packets that

Are treated the same way by each LSR

Follow the same path in MPLS network

Receive the same label

Three Key Actions

- Label binding
- Label mapping
- Label distribution

Taken by LSRs

Label Binding

An LSR determines the label that should be prepended to packets belonging to a given FEC

- Downstream binding
  - LSR on receiving end of a link
  - Packets of the FEC shall be received with chosen label
  - Upstream node to be notified
- Unsolicited
- On-demand

Label Mapping

Association between

- Input label
- Output label
- Output port / next hop

Chosen by the considered LSR

Chosen by downstream LSR

Based on routing

How can the LSR know it?

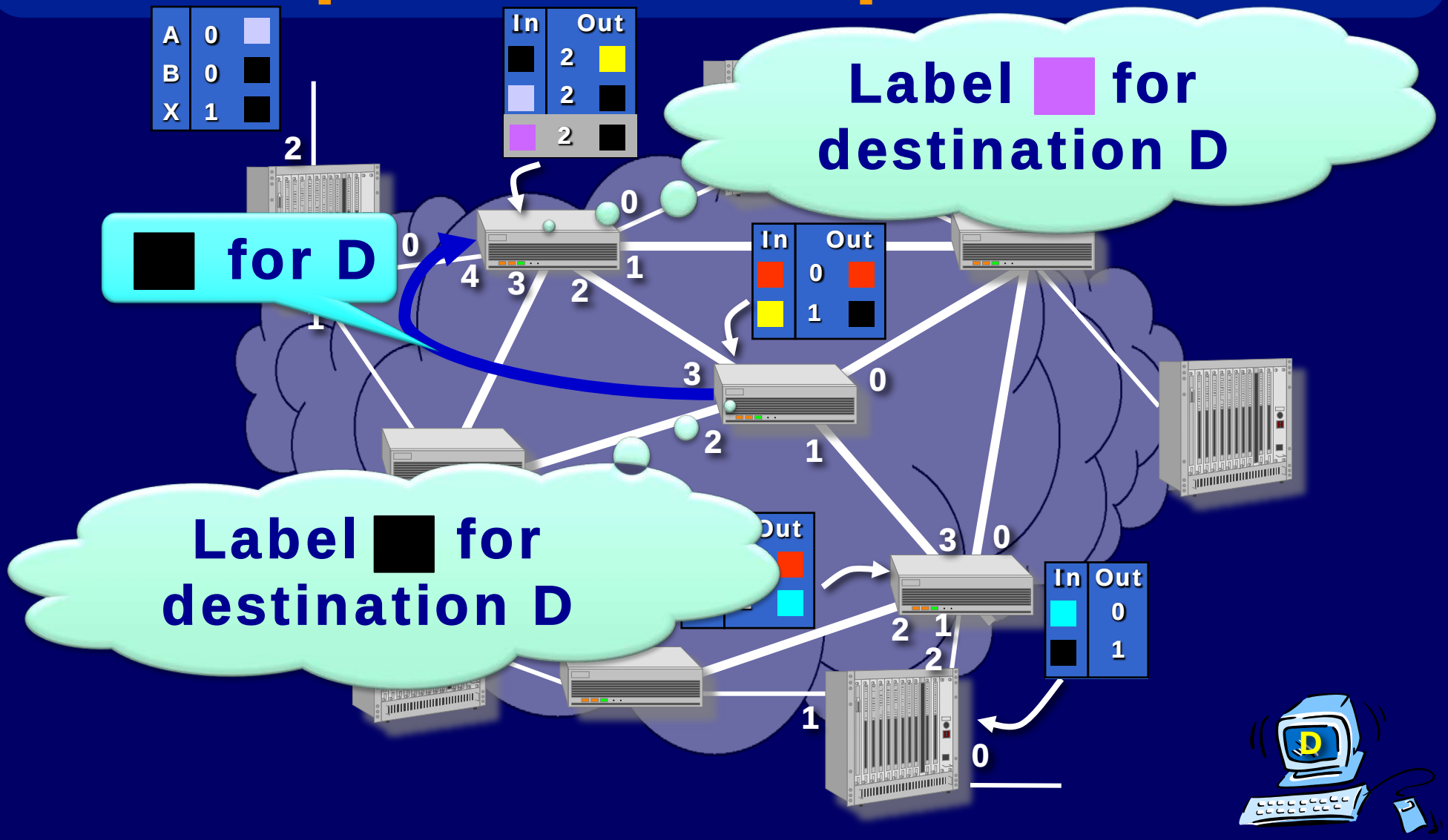
Actual creation of an LSP

Label Distribution

Notification of the label chosen for a given FEC

- **Follows label binding**
- **An LSR that has made a binding, distributes it to neighboring LSRs**
  - **Or at least to the upstream one**

Putting it all together: Sample LSP Setup



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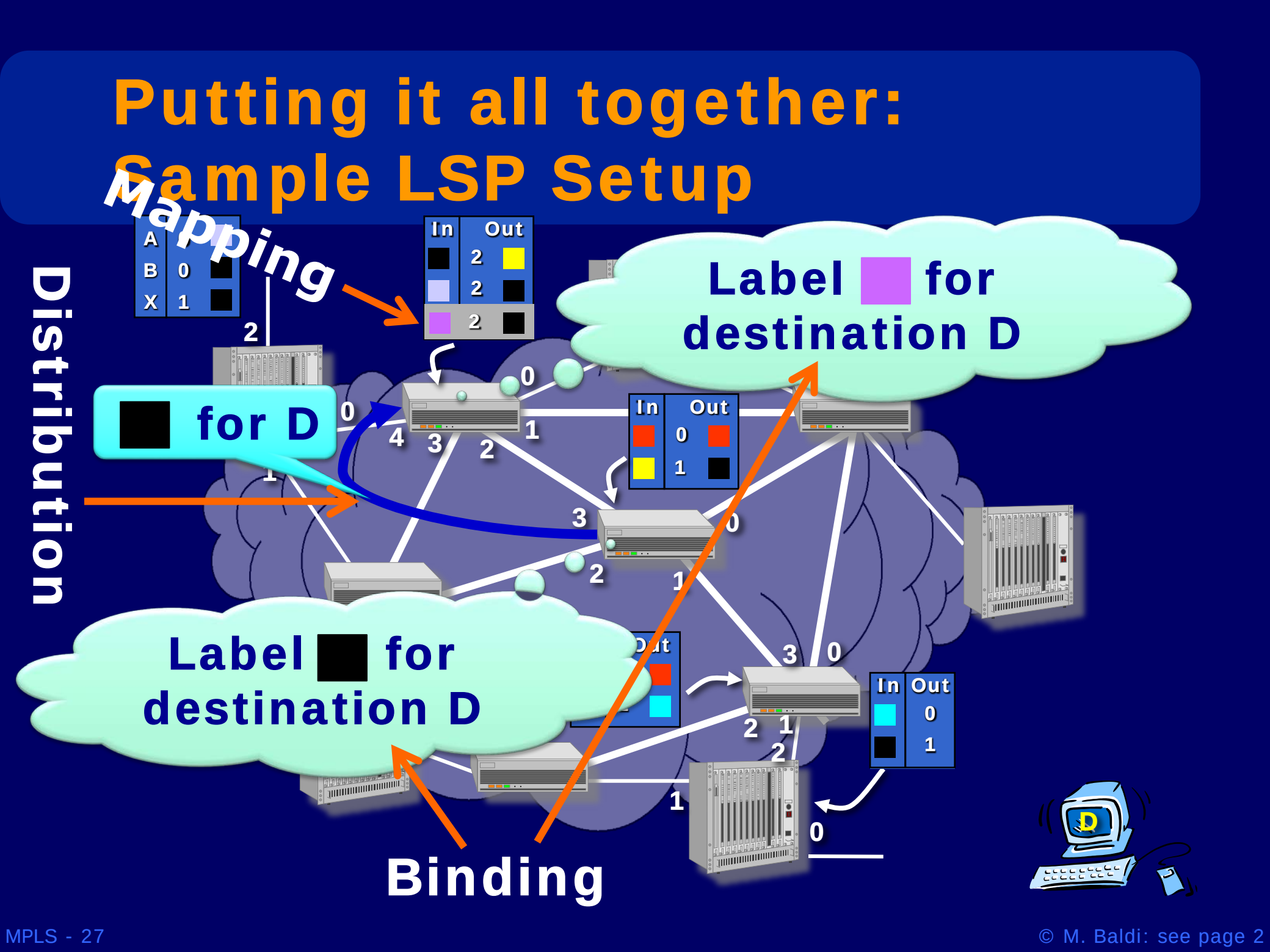


Static label binding (and mapping)

- Through management
- Equivalent to PVC ATM
- Non-scalable
- No interoperability among managing systems
- Impossible to have LSPs through different networks

类似于PVC ATM

管理系统之间没有互操作性

不可能让LSPs通过不同的网络

Dynamic Label Binding

- Data / traffic driven 数据/流量驱动
  - Triggered by data packets 由数据包触发
- Control driven 控制驱动
  - Triggered by control message
    - Signaling
    - Routing

Control Driven Label Binding

- **Topology based** 基于拓扑结构
  - The creation of LSPs is linked to the discovery of routes towards destinations

    LSPs的创建与前往目的地的路由发现相关
- **Explicit creation of LSPs**
  - Explicit signaling
  - Initiated by label edge routers

    由标签边界路由器初始化

Label distribution protocols

三种选项，并不兼容

Three alternatives (incompatible)

- Routing protocol: BGP
  - Only topology based

BGP：只基于拓扑结构

- Label distribution protocol (LDP)
  - Designed for the purpose

LDP专门针对标签设计的协议

- Resource reservation protocol (RSVP)
  - Designed for allocation in integrated service networks

资源保留协议：专为综合业务网络的分配而设计

Routing protocols

路由协议

Used to determine LSP routing

- Impact label mapping phase

作用于Mapping阶段

- Indirectly determine packet routing

并不直接决定包的路由

Routing protocols

Existing protocols

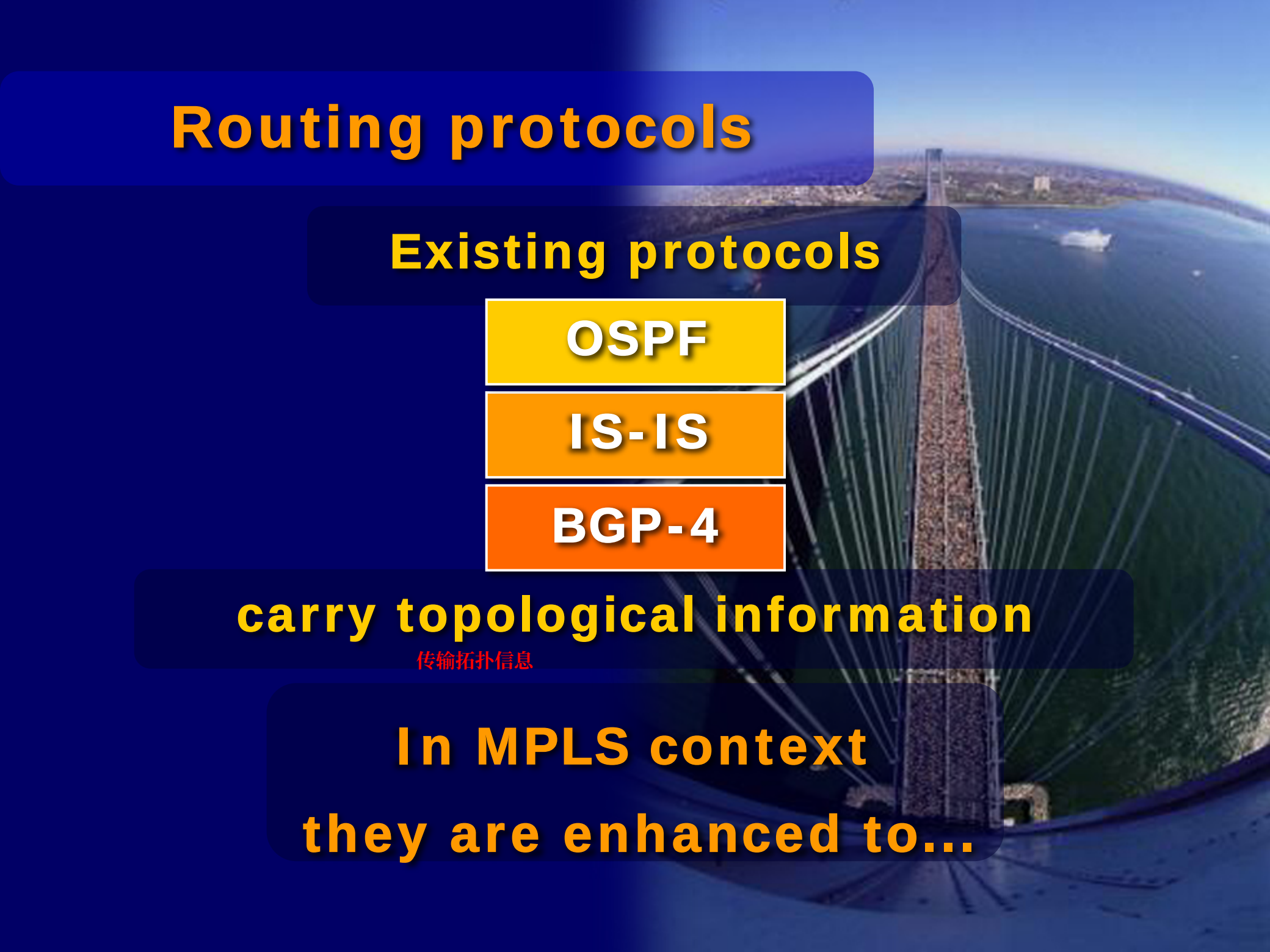
- OSPF
- IS-IS
- BGP-4

carry topological information

传输拓扑信息

In MPLS context

they are enhanced to...



Routing protocols

...carry information to constraint routing decisions (constraint data)

传输的信息用来限制路由决定

- Capacity of links 链路的吞吐能力
- Link utilization 链路的利用
- Dependencies among links 链路之间的依赖关系
  - Used for fault recovery 用来恢复错误

Enhanced routing protocols

增强路由协议

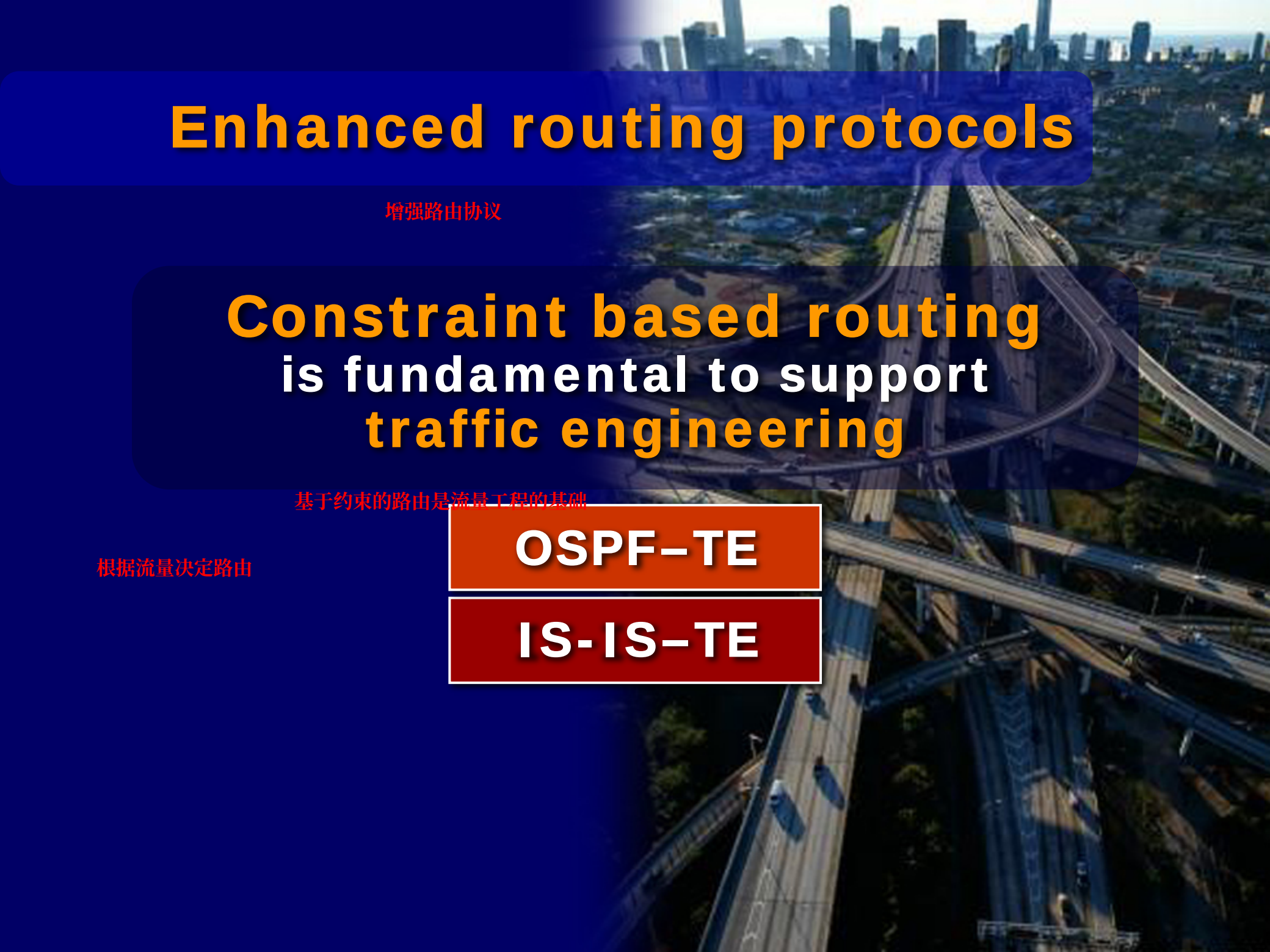
Constraint based routing
is fundamental to support
traffic engineering

基于约束的路由是流量工程的基础

根据流量决定路由

OSPF–TE

IS-IS–TE



Hop-by-hop Routing

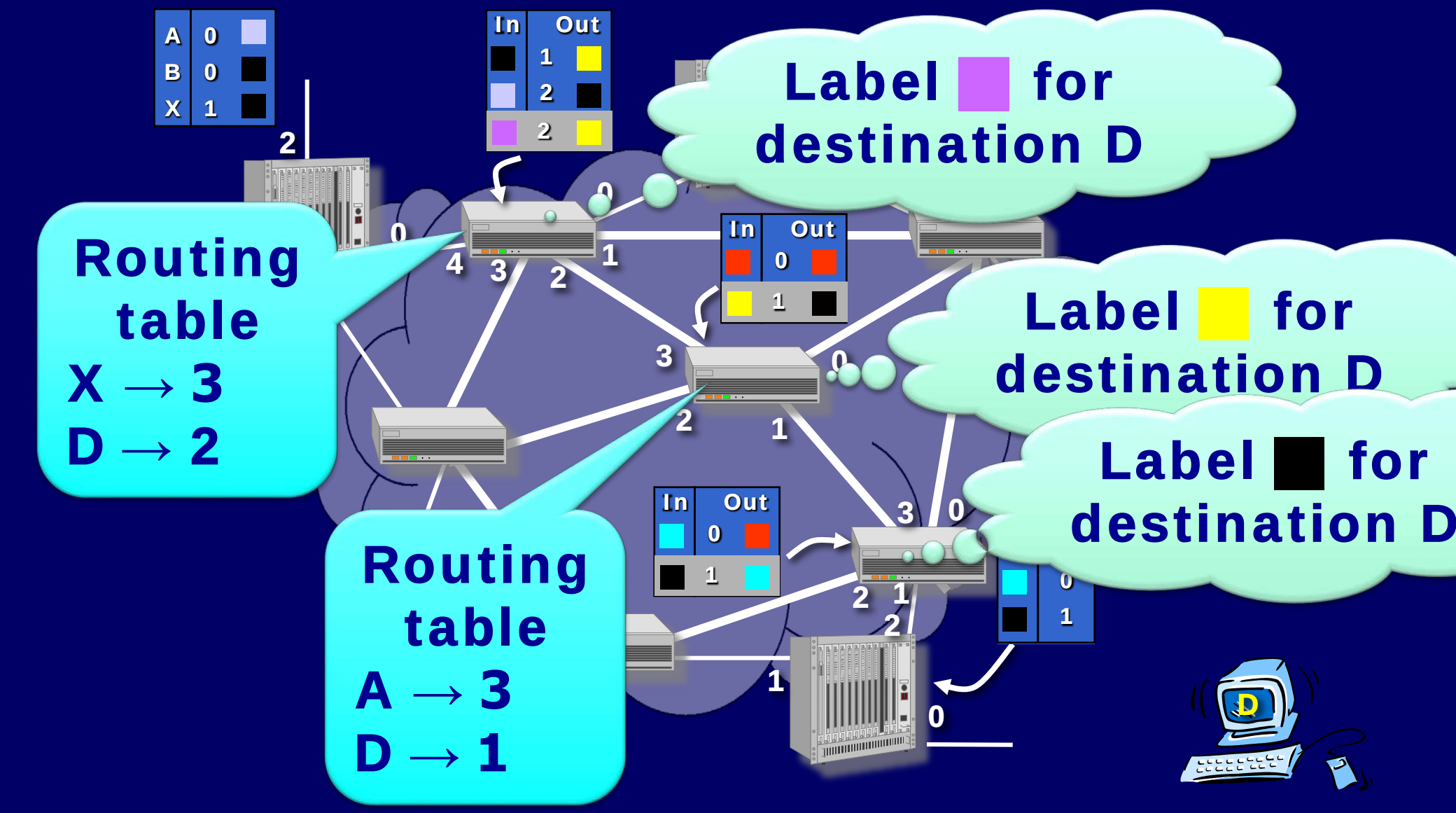
Each LSR decides the next LSR of the LSP path

- **E.g., Based on IP routing table**
- **Same principle and outcome (route) as in traditional IP routing**

Hop-by-hop Routing Procedure

- Pick label for upstream link
  - Label binding
- Map it to
  - Next hop
    - Address of connected interface of next LSR
  - Label announced by next LSR

Hop-by-hop Routing Example



Explicit constraint based routing

- A single switch chooses the path of a whole LSP
  - For example, ingress LSR
  - Explicit routing
- The choice is constraint based
  - Constraint based routing

Constraint Based Routing

限制基于的路由

- Distributed operation impossible
- → No unique route selection criteria
  - → Conflicting constraints
- → Hard to maintain constraint information synchronized
  - → It changes more frequently than topology information

Label distribution protocols

LDP

Should be modified

- **CR-LDP**
  - Constraint-based routing LDP
- **RSVP-TE**
  - RSVP for Traffic Engineering

To be used with OSPF-TE and IS-IS-TE

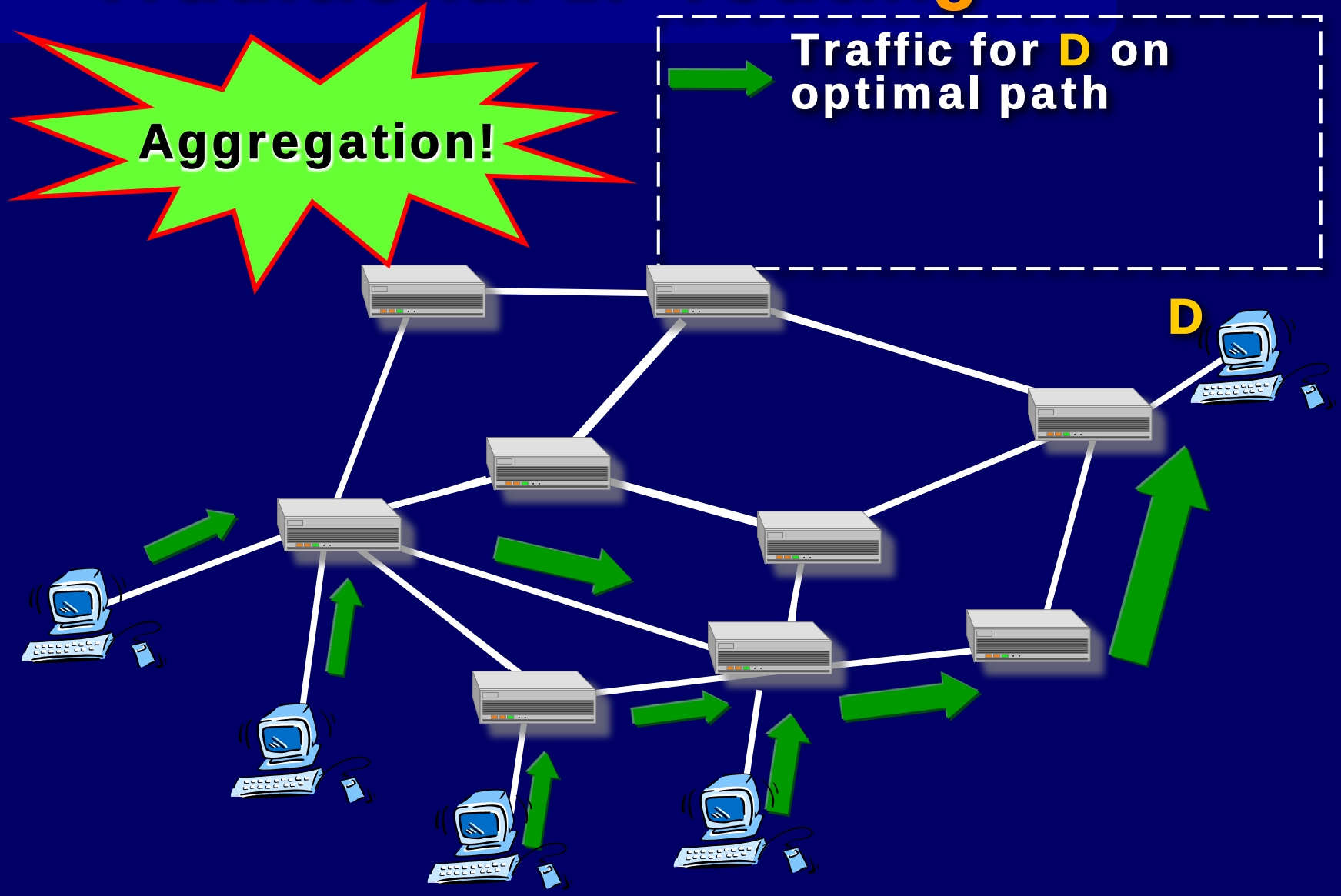
New possibilities

- Traffic engineering (TE)
- Guaranteed quality of service
  - Not yet supported (QOS)
- Per-class traffic engineering (针对一类数据的TE)
  - Synergy with DiffServ
- Fast fault recovery (错误快速修复)
  - In less than 50 ms

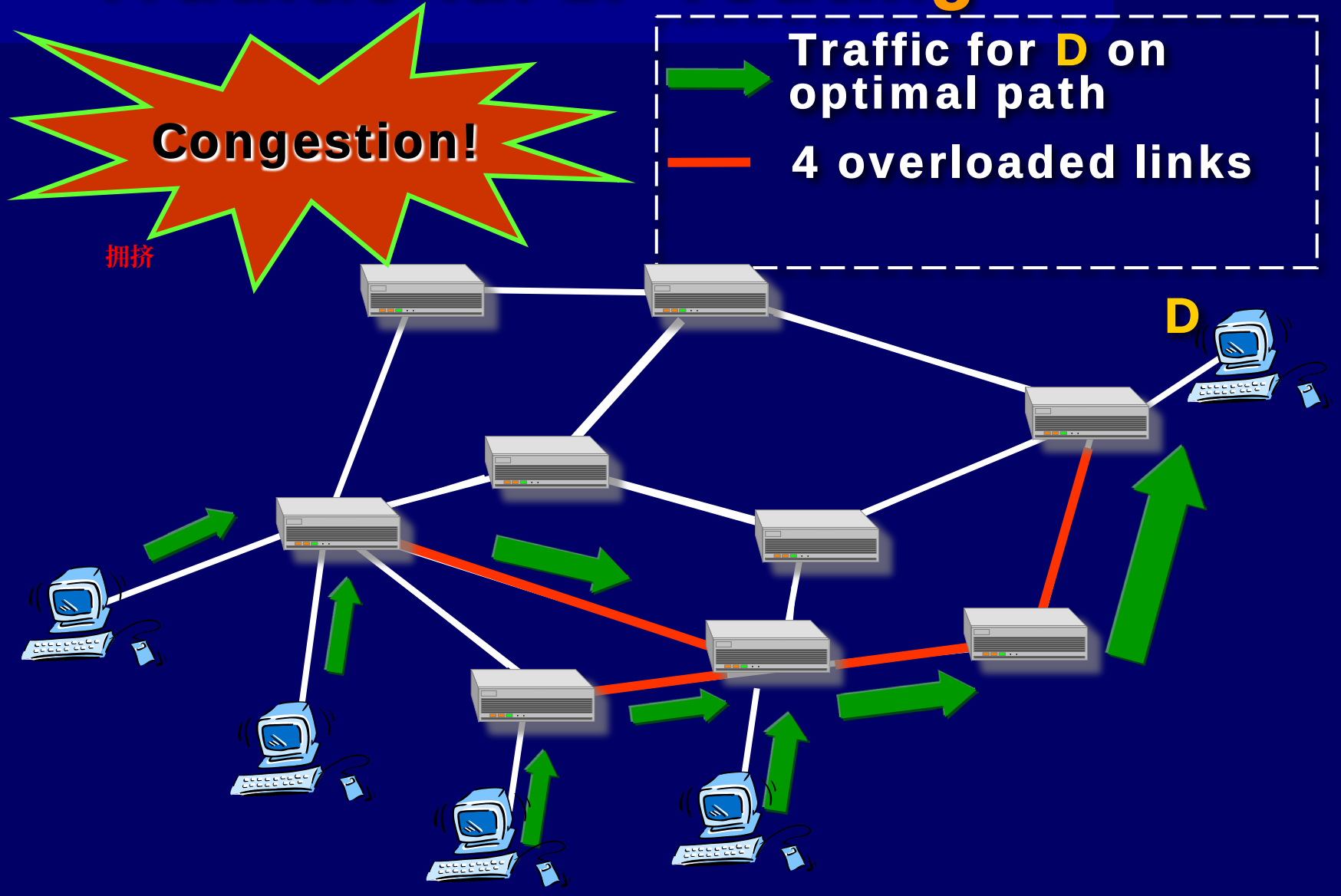
Traffic Engineering

Motivation and enablement

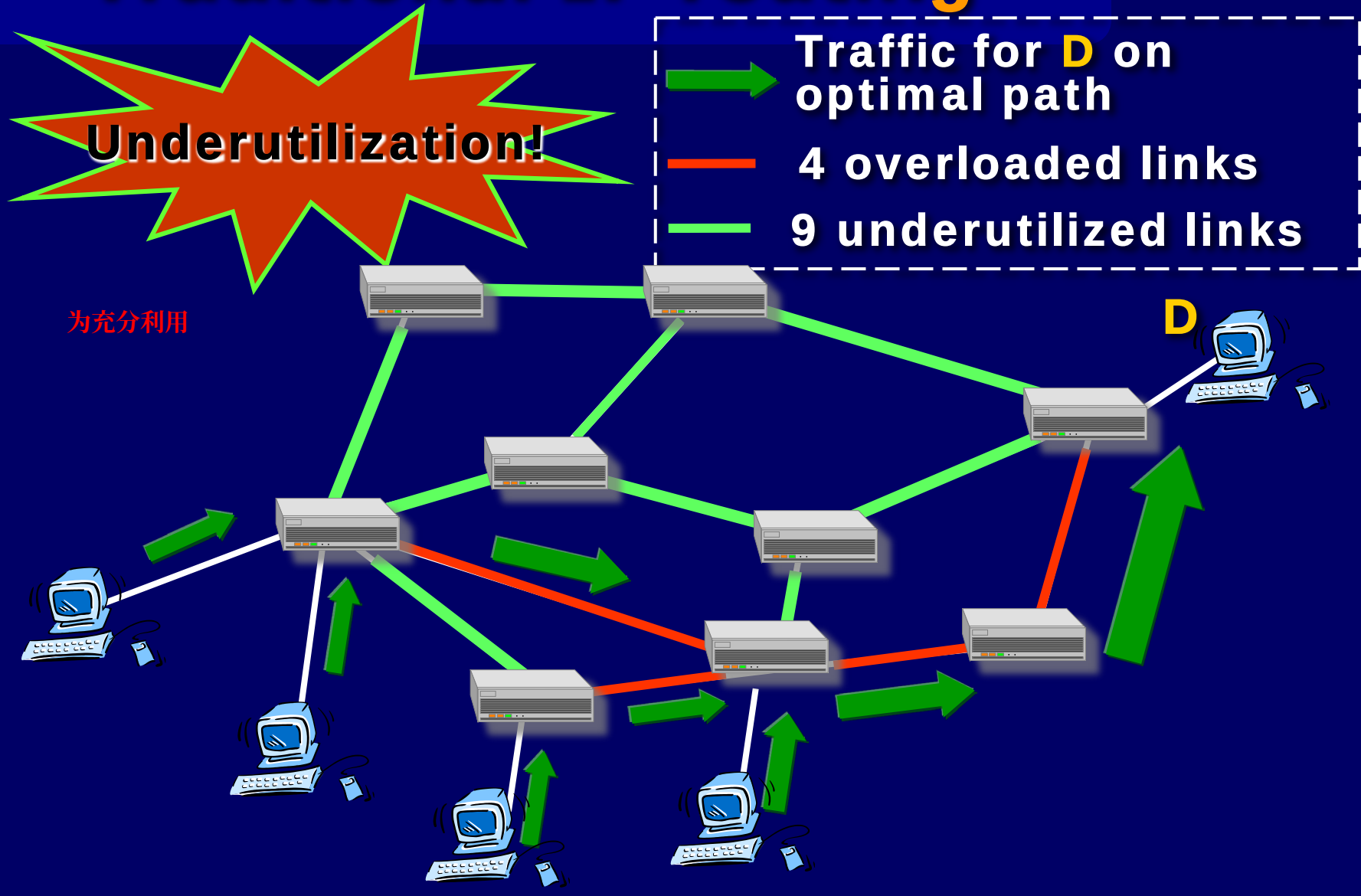
Traditional IP routing



Traditional IP routing

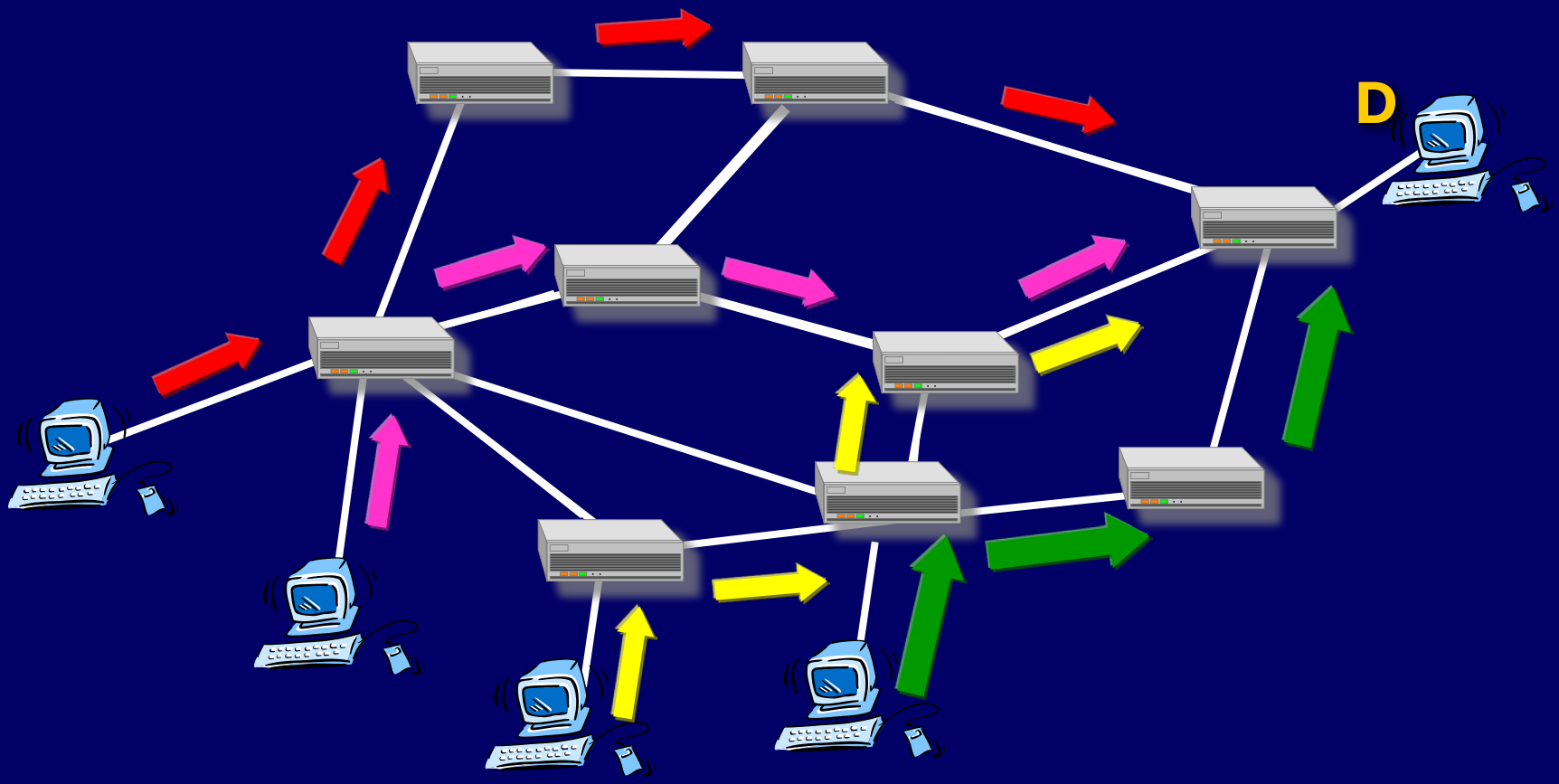


Traditional IP routing

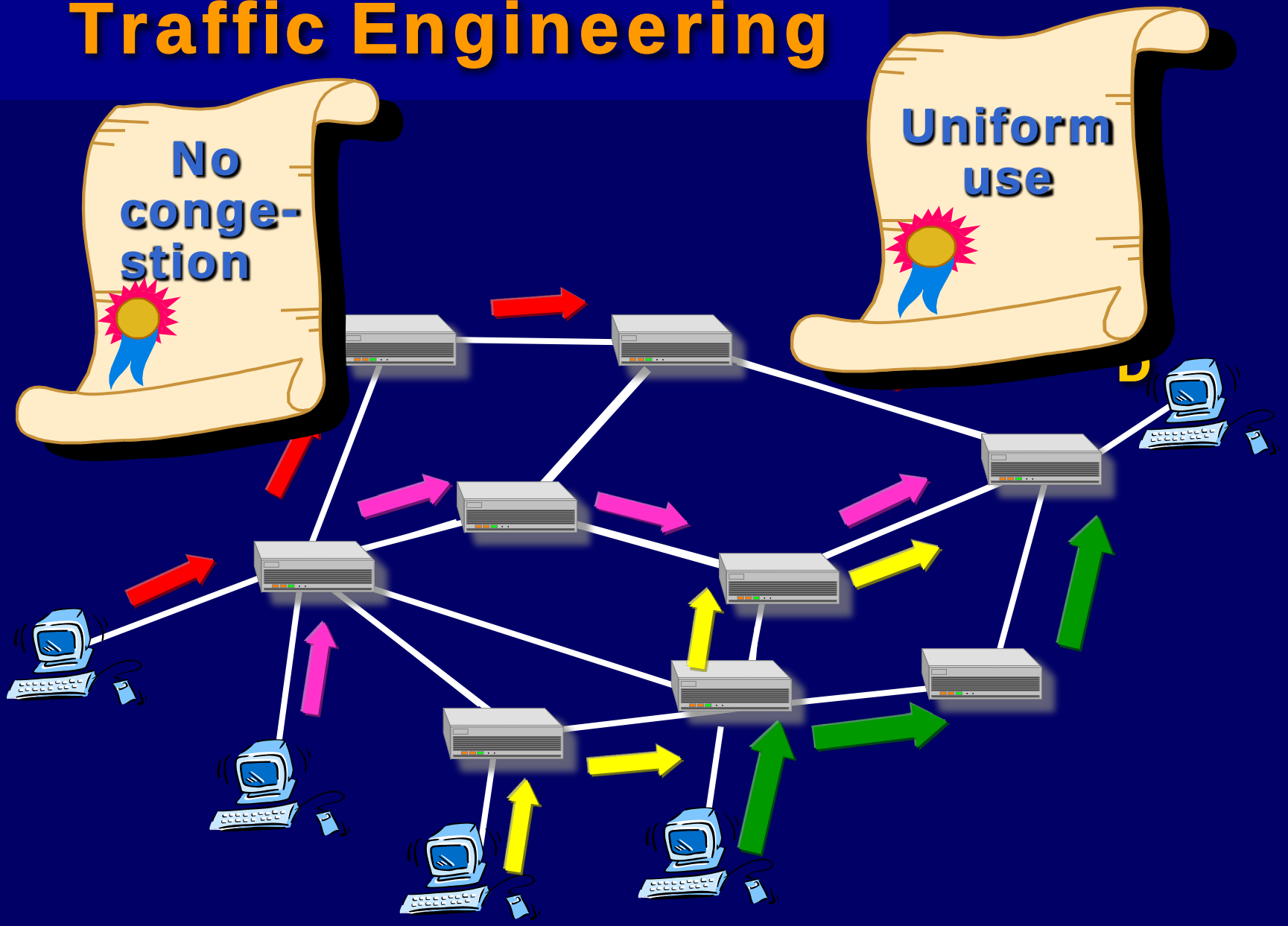


Traffic Engineering

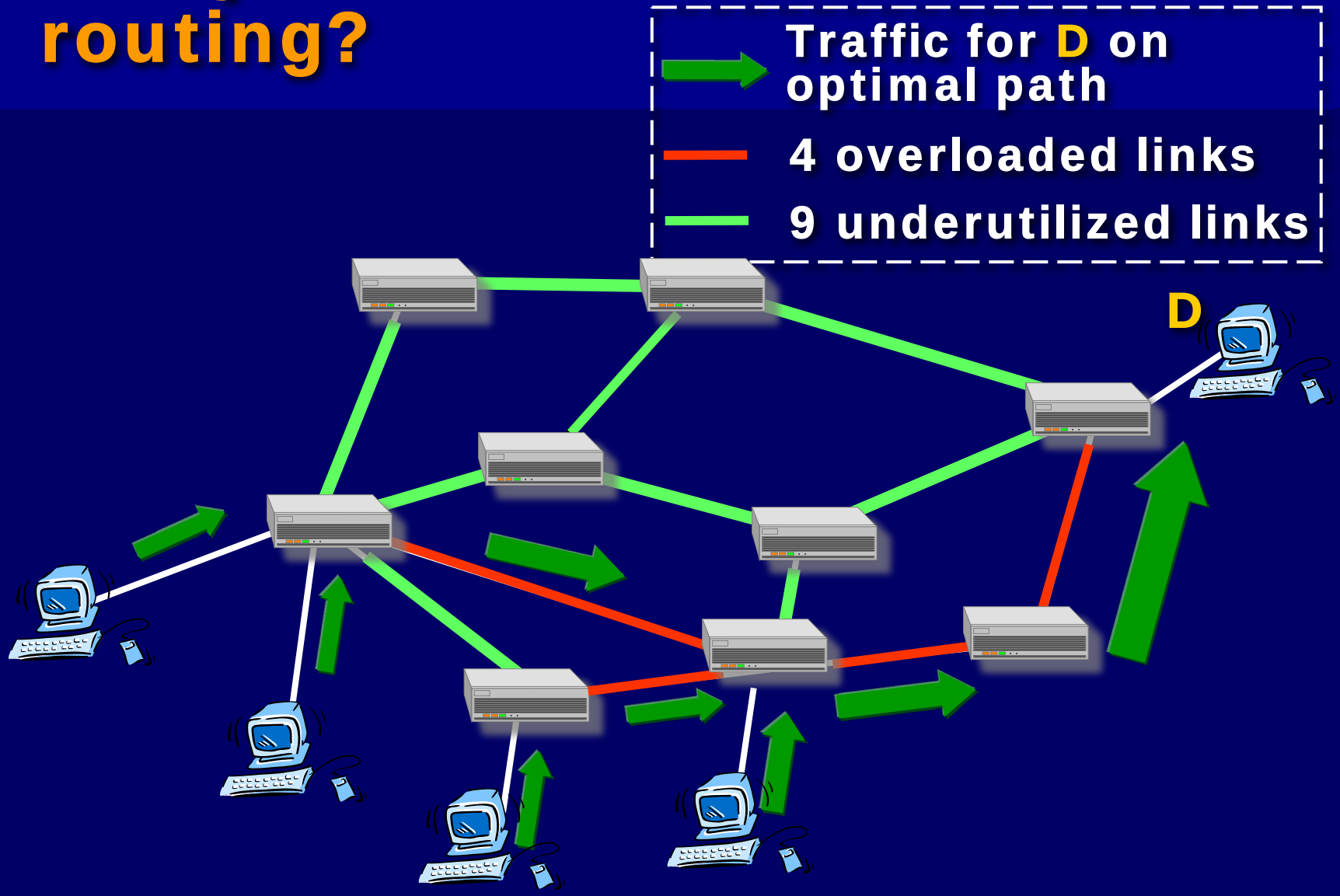
Enables traffic distribution



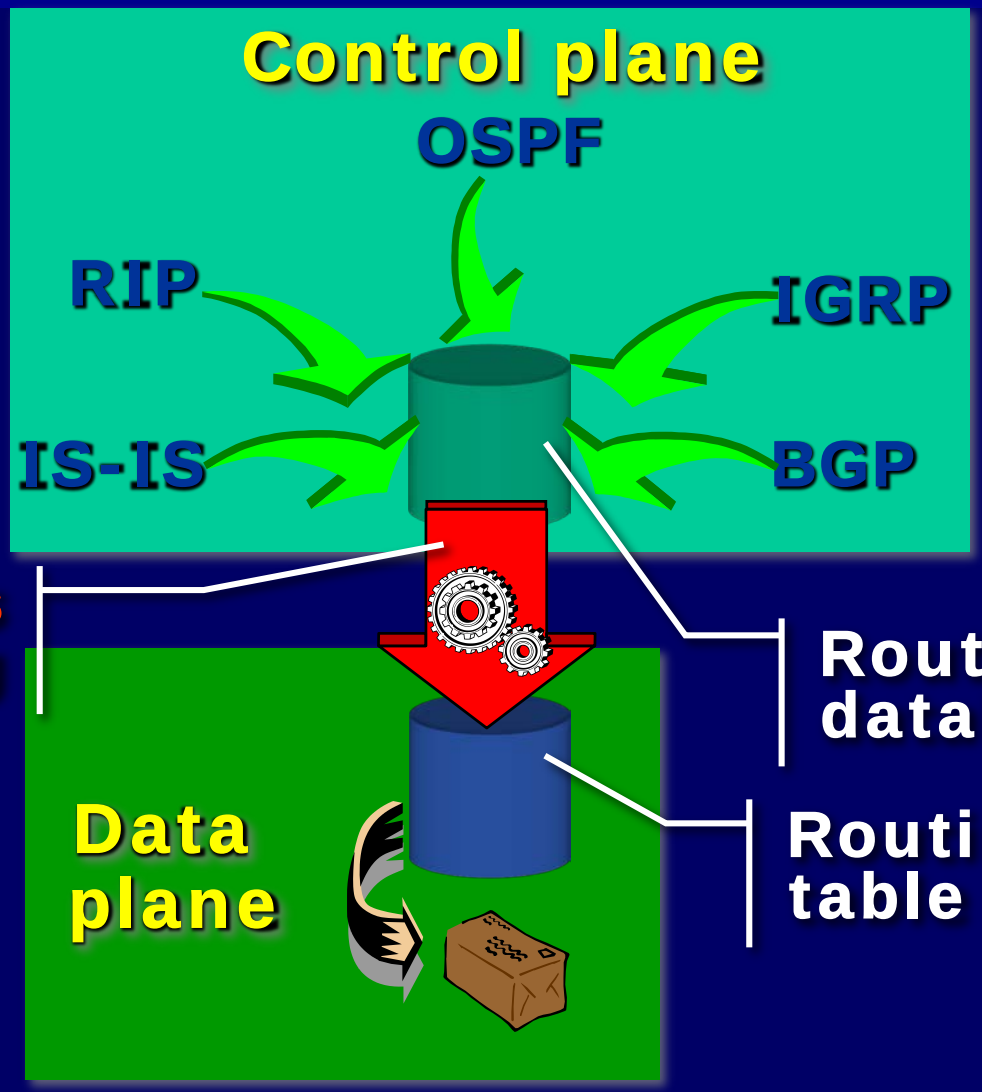
Traffic Engineering



Can you do it with traditional IP routing?

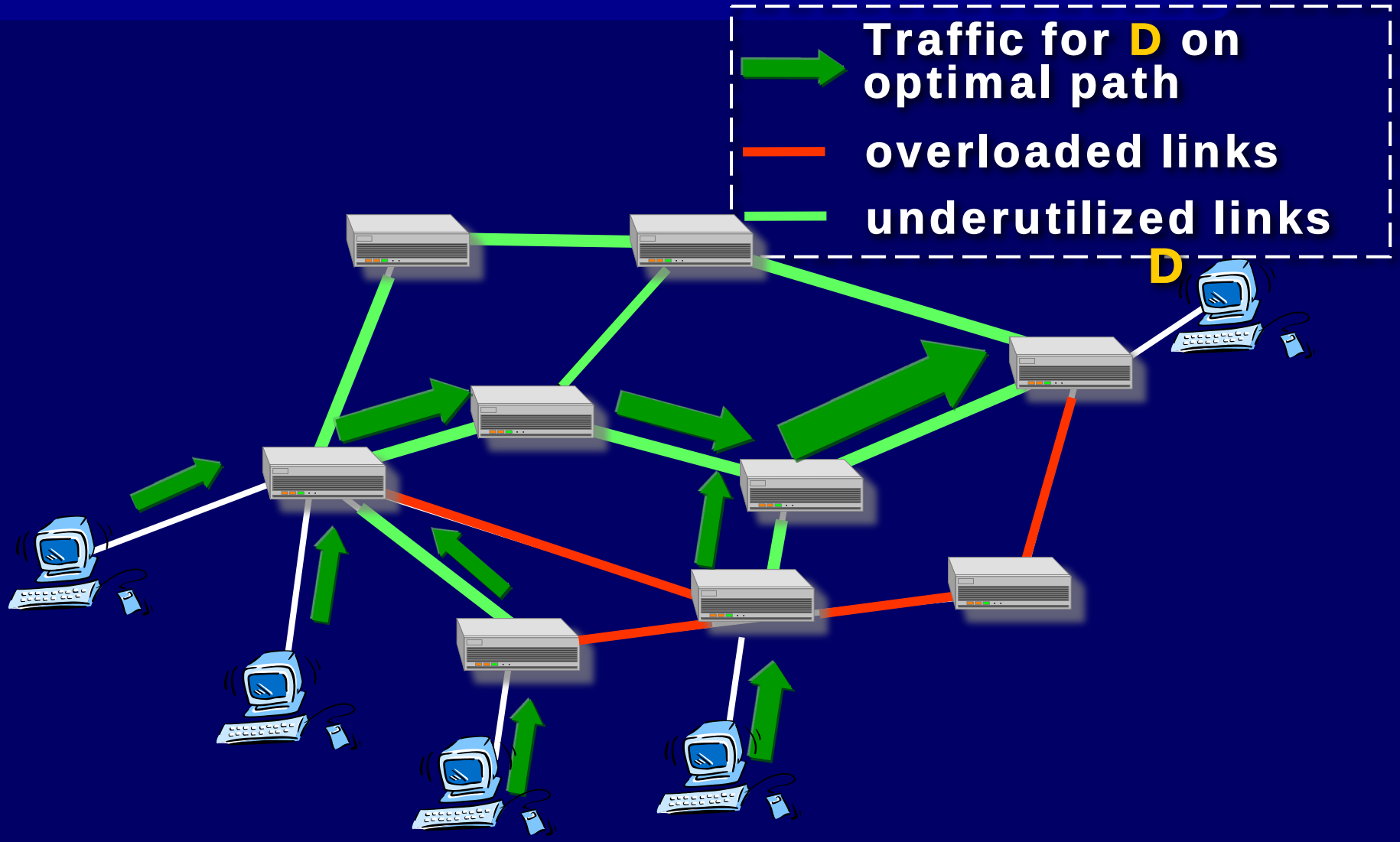


Control plane and data plane

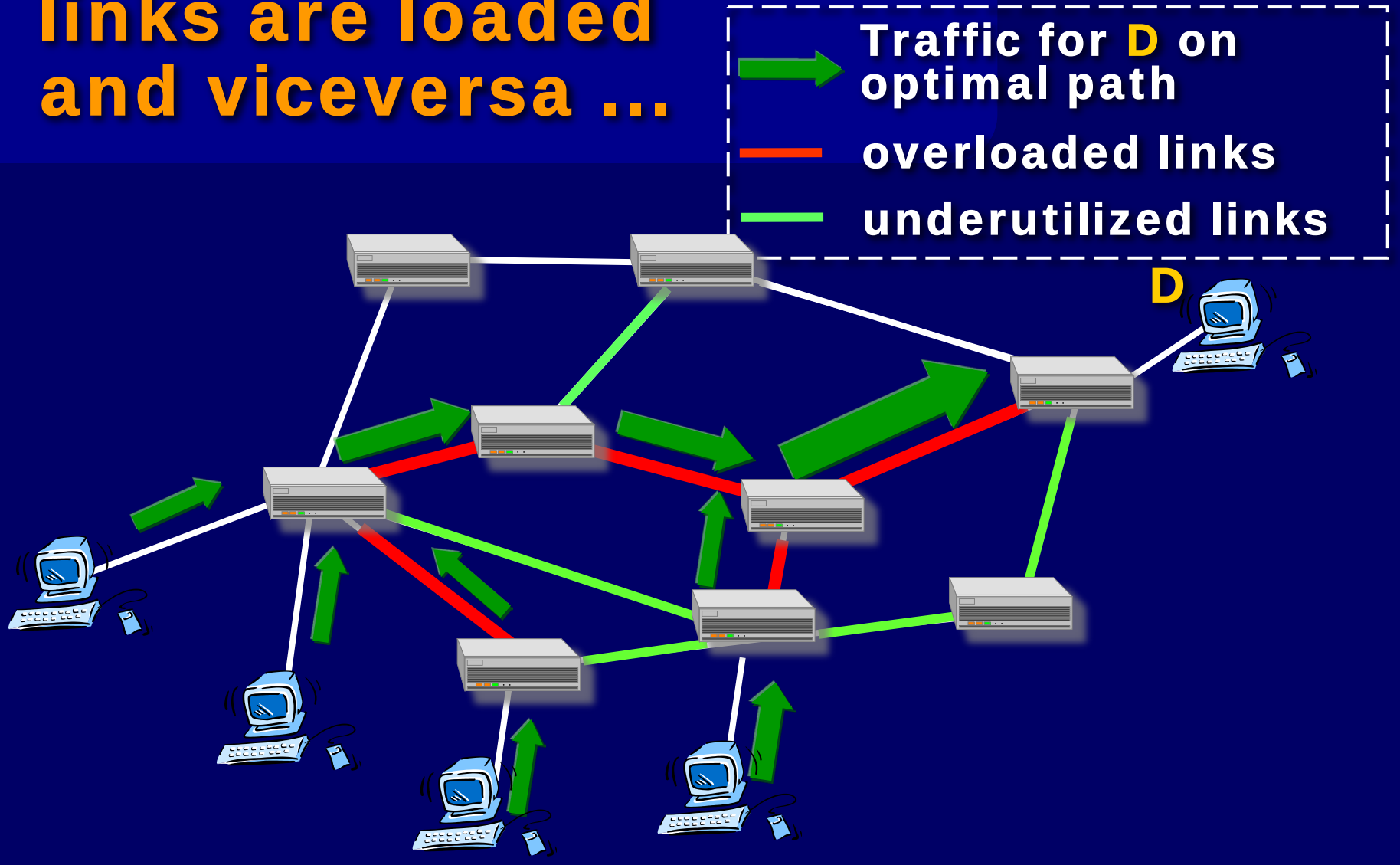


Route IP

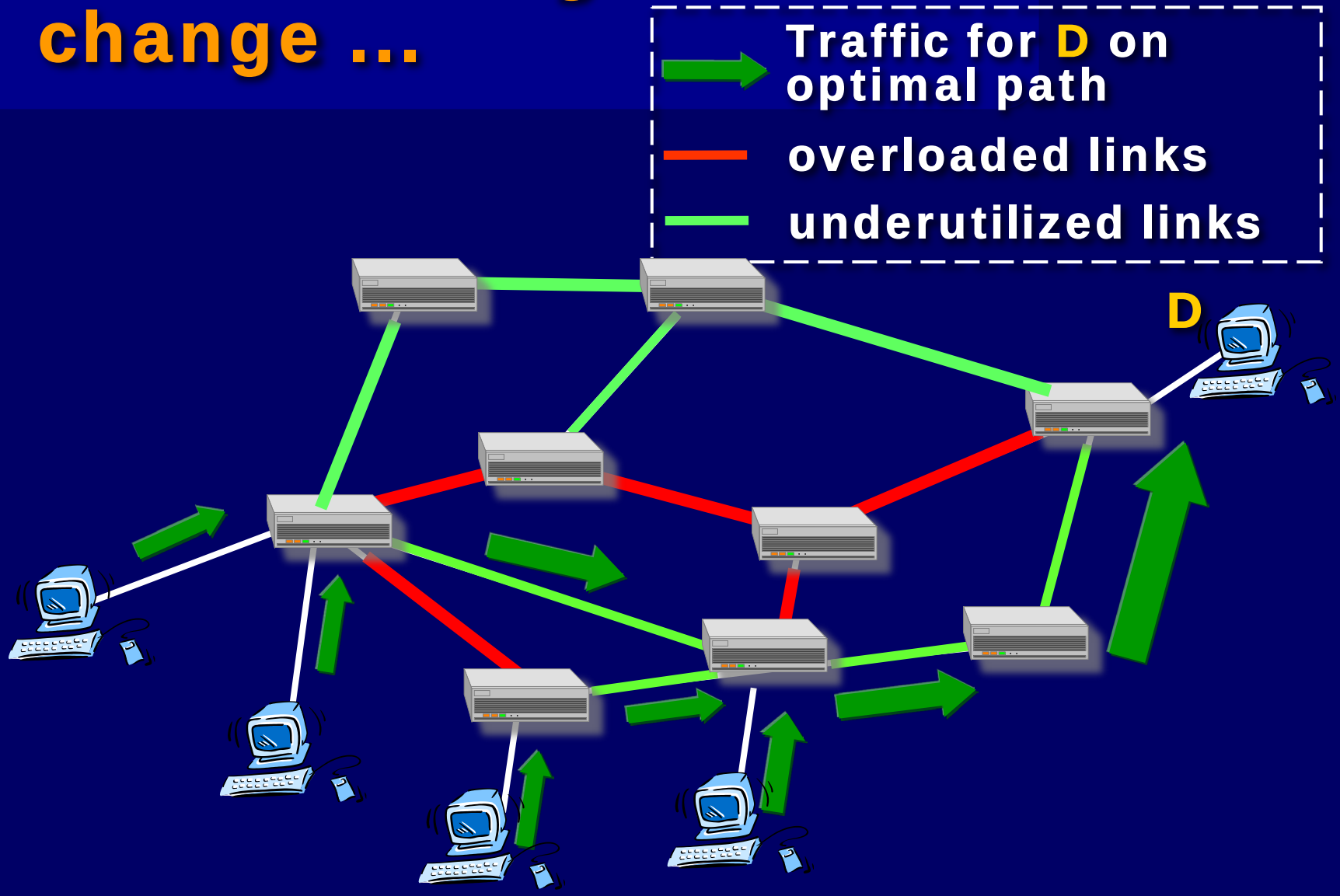
It would be possible to choose paths according to load



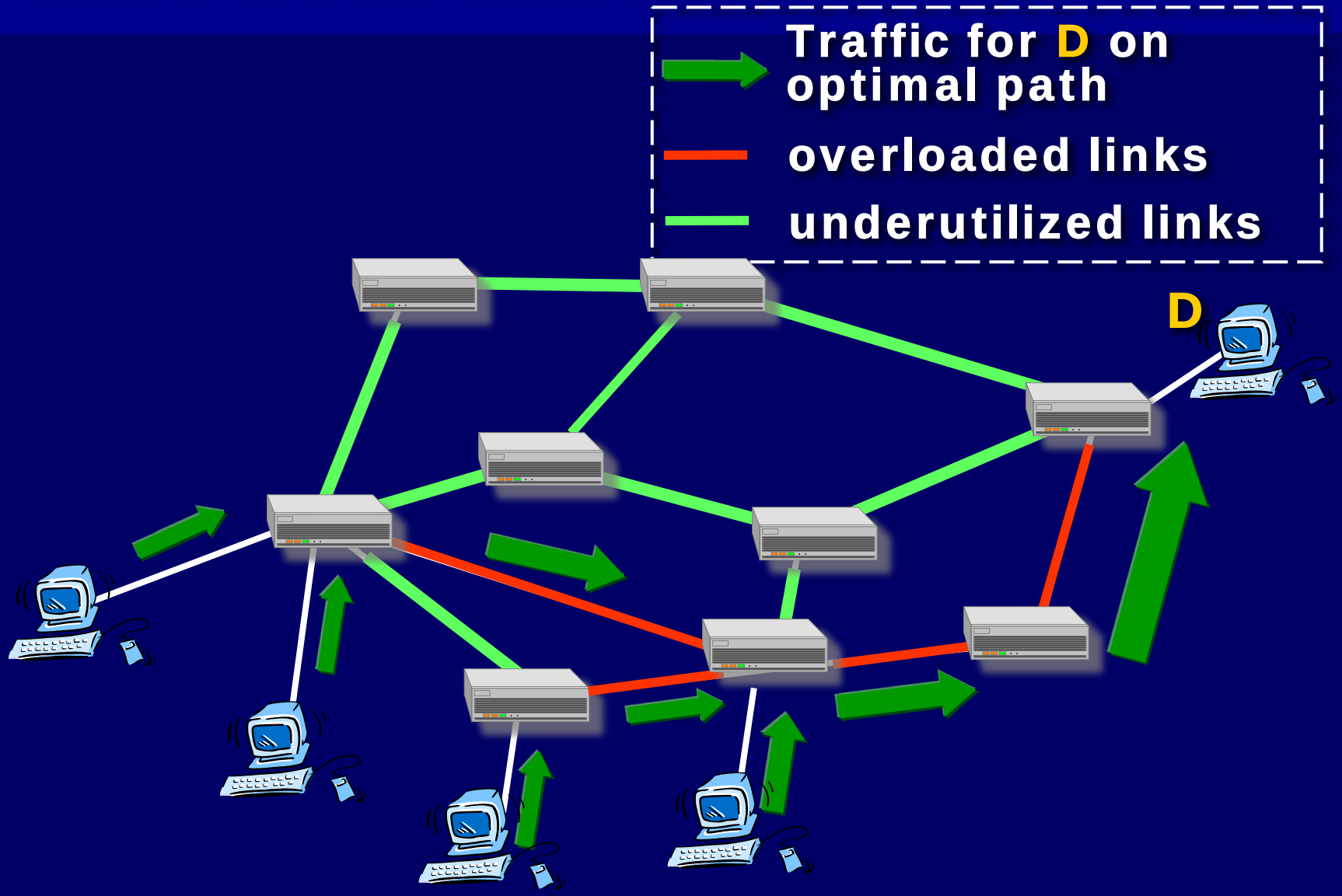
In such way, unloaded links are loaded and viceversa ...



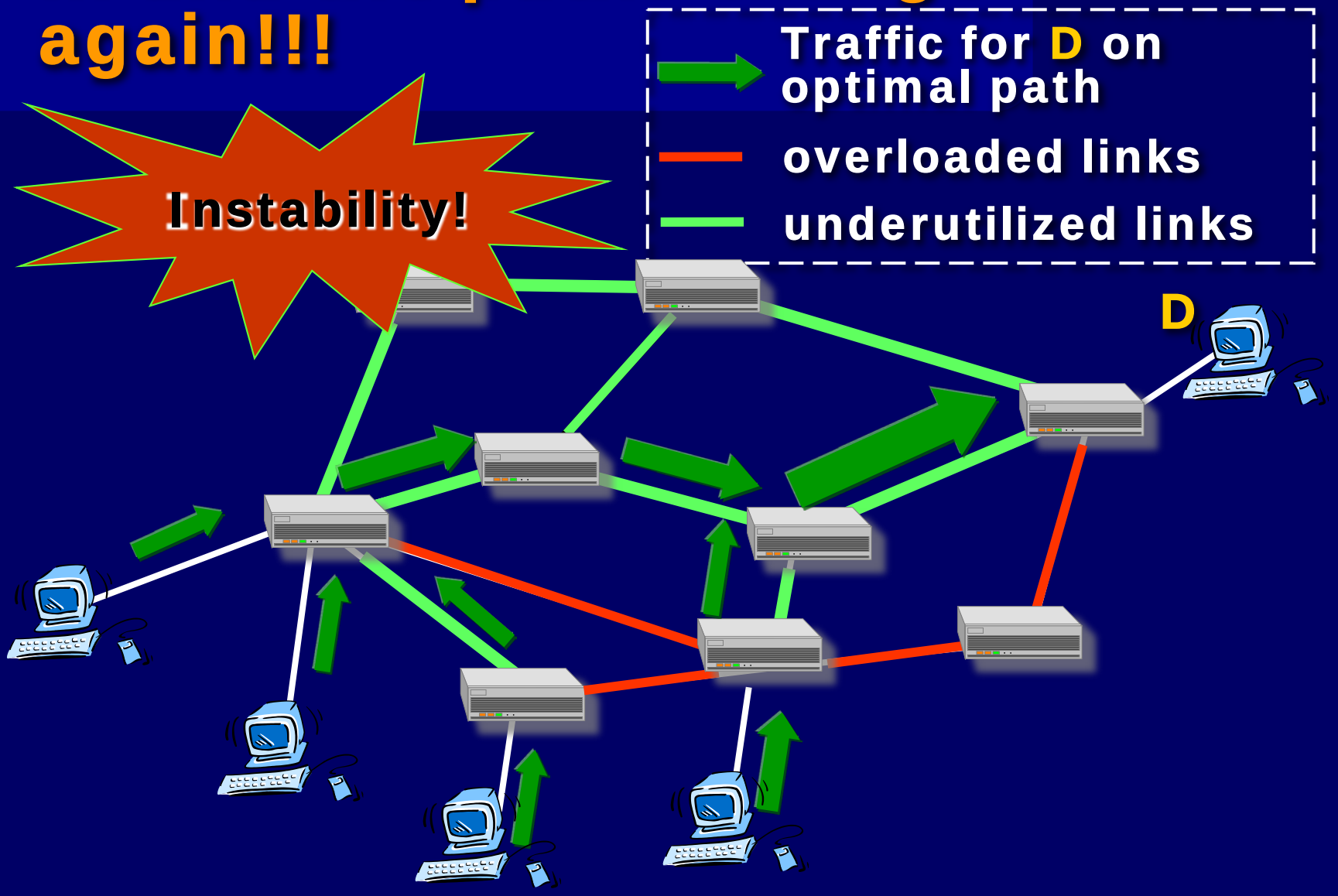
... and routing tables change ...



...so does the link load...



... and the paths change again!!!



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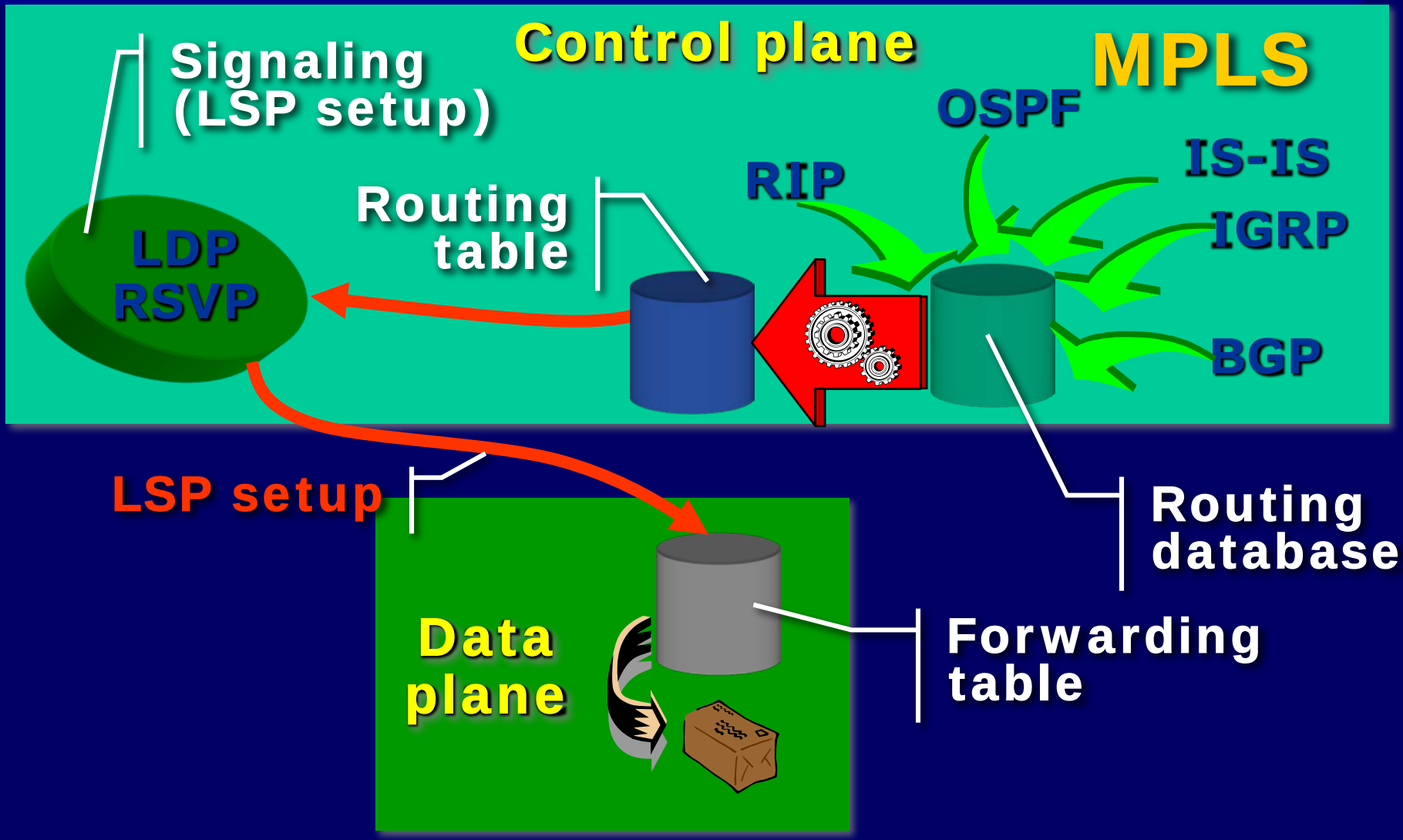

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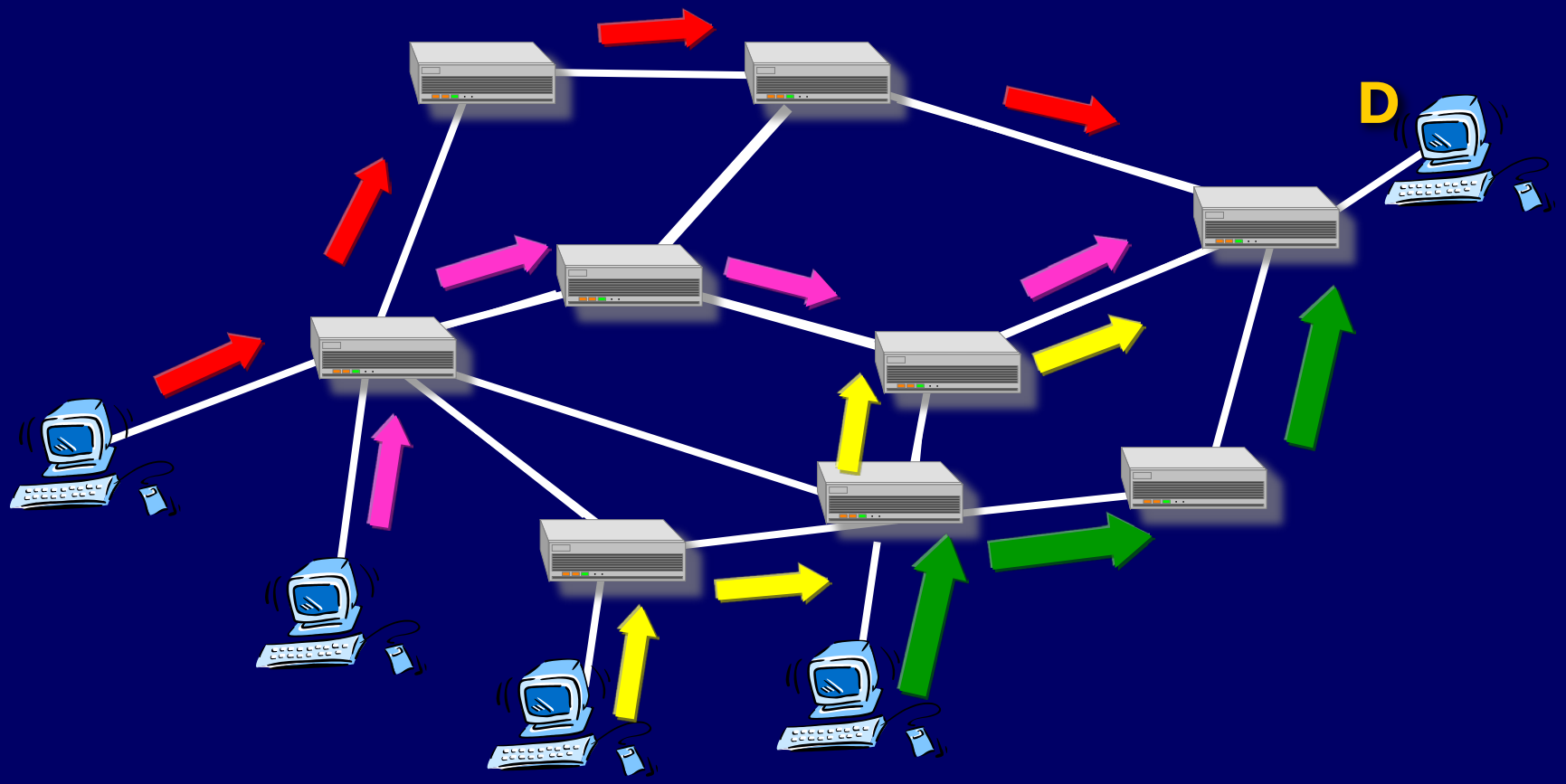
Traffic Engineering with MPLS



Traffic Engineering without MPLS

- ATM has so far been used for traffic engineering on IP networks
  基于IP的网络，没有MPLS的话，实现太难了
- Two control plans
  两个控制方案
  - Routers are ATM-unaware
    ATM意识不到路由器
- Great number of adjacencies
  - Limitated scalability
    众多邻接关系

限制了扩展性

Traffic Engineering with MPLS

MPLS is IP-aware

Only one control plan operating on physical topology 只有一个控制方案操作于物理拓扑

简单，高拓展性

➔ **Simpler**

➔ **Greater scalability**

MPLS extensions

- MPλS (MPLambdaS) 主要应用于光通信
  - MPLS control plans in optical networks
- GMPLS (Generalized MPLS) 广义MPLS
  - MPLS control plane in any network 他的控制仪表盘作用于任何网络
    - Packet, circuit, optics, etc...

Adding CoS and QoS

Resources and service modes may be associated to a FEC at LSP setup

Explicit support is required in LSR data plan and control plan

Class of service (CoS)

- Relative priority among different FECs
- It does offer absolute guaranties
- Support of DiffServ model
  - Per-hop behavior
  - EF (expedite forwarding), AF (assured forwarding)
- Per class traffic engineering
  - DS-aware traffic engineering

Quality of service (QoS)

Specific guaranties on

- Bandwidth
- Delay
- Burst size

Advantages of QoS in MPLS

Unified network supporting all types of services

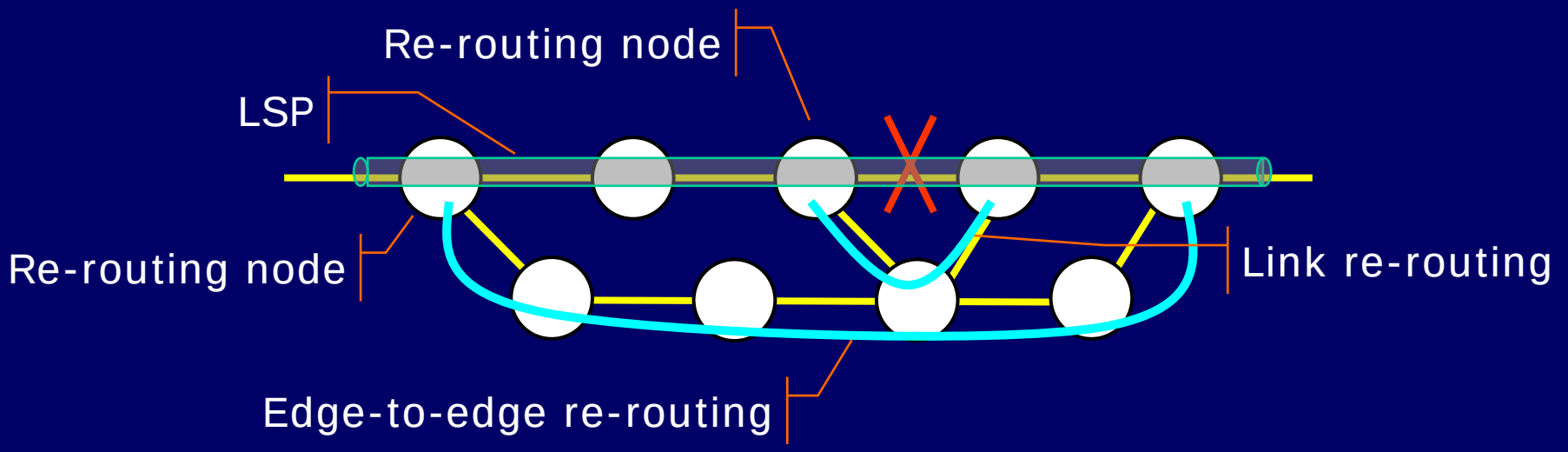
(marketing message)

- **Support of QoS and real-time services on IP (e.g., voice) is not ready**
- **A lot of multi-service networks now have a paradigm "Ships-in-the-night"**
  - **ATM protocols are ATM typical services**

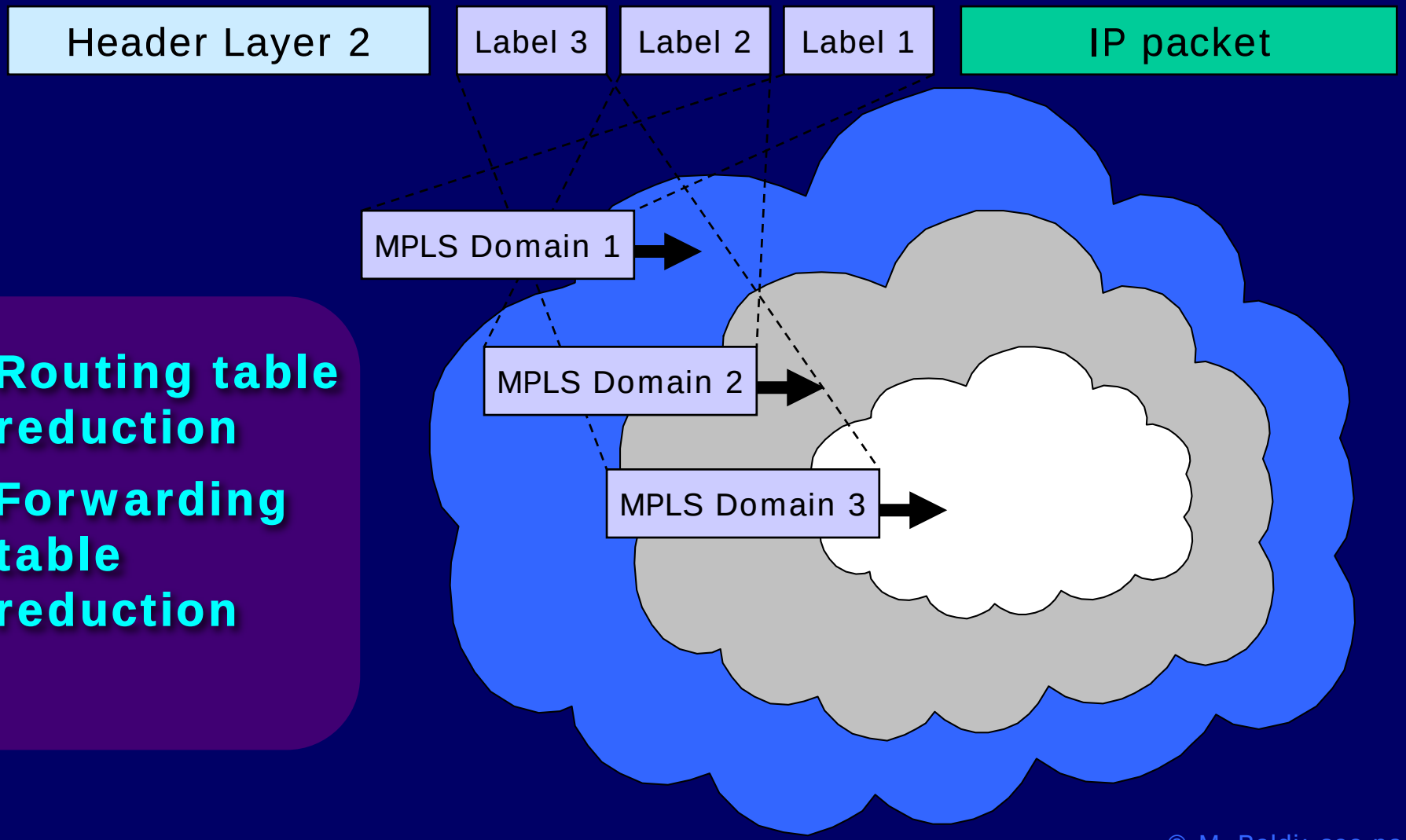
范例

  - **MPLS control plan for IP services**

Fast Fault Recovery



Label Stack hierarchy and scalability



- **Routing table reduction**
- **Forwarding table reduction**

MPLS and scalability

- MPLS labels introduce hierarchy
  - Various hierarchical levels, as needed for the necessary scalability
- Routing tables of transit routers do not have to be comprehensive
  - LSP between edge routers
- (Simpler and faster exact match of labels rather than longest prefix matching)

Penultimate Hop Popping (PHP)

- The last but one node on the path of an LSP pops the label
  - The LER routes the packet based on IP address (or next label in stack)
- Distribution of label 3 indicates (implicit) PHP
- Explicit PHP: label 0 is swapped
  - When shim header is needed
    - E.g., EXP bits

VPN: Virtual Private Network

Services similar to those of a private network, but provided on a public infrastructure (IP)

- Privacy and security
- Overlapping addressing spaces (private)
  - Non-unique addresses
- Class of Service (CoS) and Quality of Service (QoS)

VPN可以进行QOS和COS

VPN based on MPLS

- Labels “hide” IP addresses of users on the public network
  - Allow for ovelapping address spaces
- Service flexibility
  - FEC

VPN based on MPLS

- MPLS allows a scalable solution for VPN services
  - Other approaches require explicit setting (manual) of tunnels between each pair of websites
  - Number of VPNs
  - Number of VPN members

Standardization

- IETF – Internet Engineering Task Force
  - MPLS working group
- FR/MPLS Alliance
  - Consortium of vendors
  - Foster deployment
  - Aspects omitted by IETF
    - VoMPLS, ADSL