Routing for Multi-Layer Networks

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Agenda

- What is “Routing for Multi-layer networks”?
  - What is a layer?
  - What exists in a layer?
  - What relates layers to each other?
- Multi-layer routing approaches
  - Layer independent
  - Multi-layer cooperation
- Routing topology models for multi-layer networks
  - Pseudo-node
  - Multi-layer topology

What is “Routing for Multi-layer networks”?

- Single-layer routing is the process of identifying a path between source and destination in a layer network, utilizing resources pre-allocated to that layer network.
- Multi-layer routing is the process of identifying a path between source and destination in a layer network, utilizing resources dynamically allocated from another layer network where necessary.
- So what’s the difference?

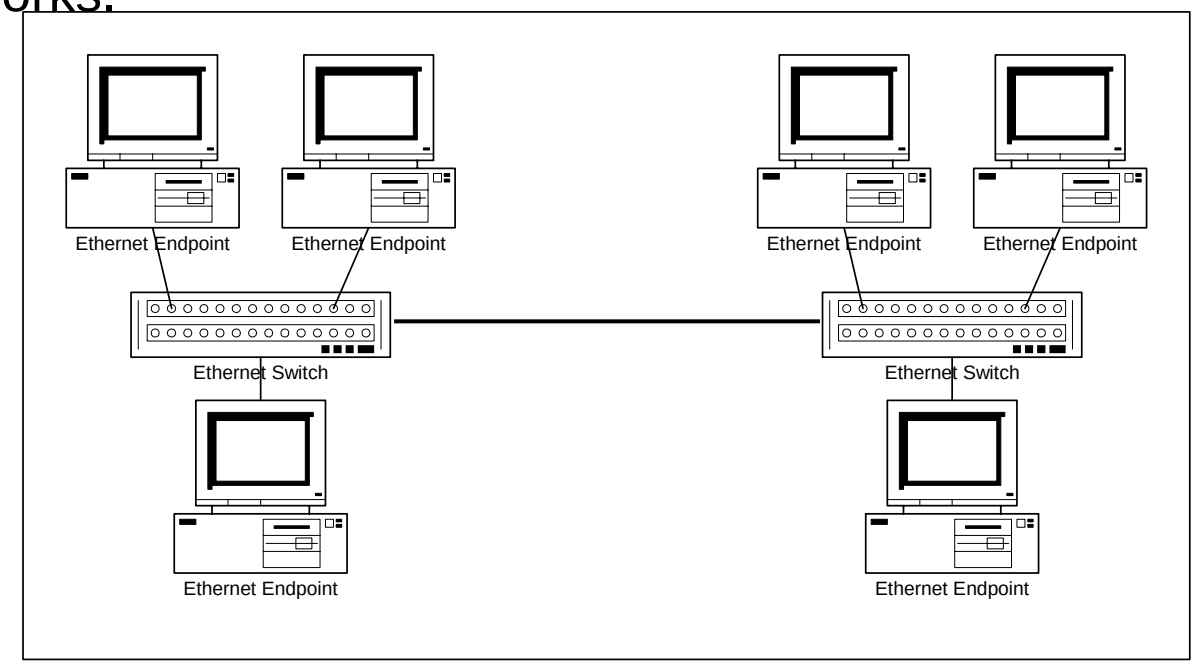
“utilizing resources *dynamically* allocated from another layer network”

So, what is a layer network?

- First, what's a layer?
  - A layer is defined by the information used by switches to carry a signal through the network.
    - Examples
      - The IP layer is defined by the fact that an IP header containing IP addresses is used to switch IP packets.
      - The MPLS-TE layer is defined by the fact that an MPLS-TE shim-header is used to switch MPLS-TE packets.
    - A layer's definition is more than specifying the header formats used for switching
      - Can also place constraints on the payload being carried
        - » Ex. Ethernet and 1500-byte MTU
      - Can also constrain the frequency of data elements

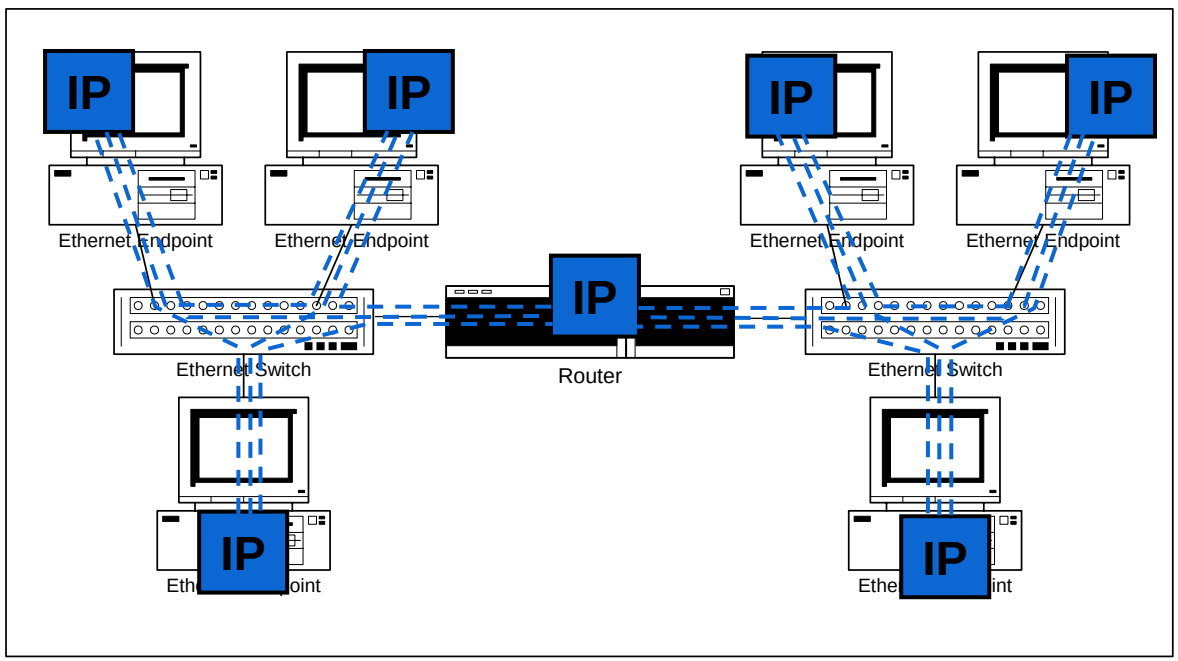
So, what is a layer network?

- A layer network is defined as a set of endpoints and switches that participate in a layer, and are able to connect to each other
  - Sets of endpoints and switches in a layer that are unable to connect to each other are considered to be separate layer networks.



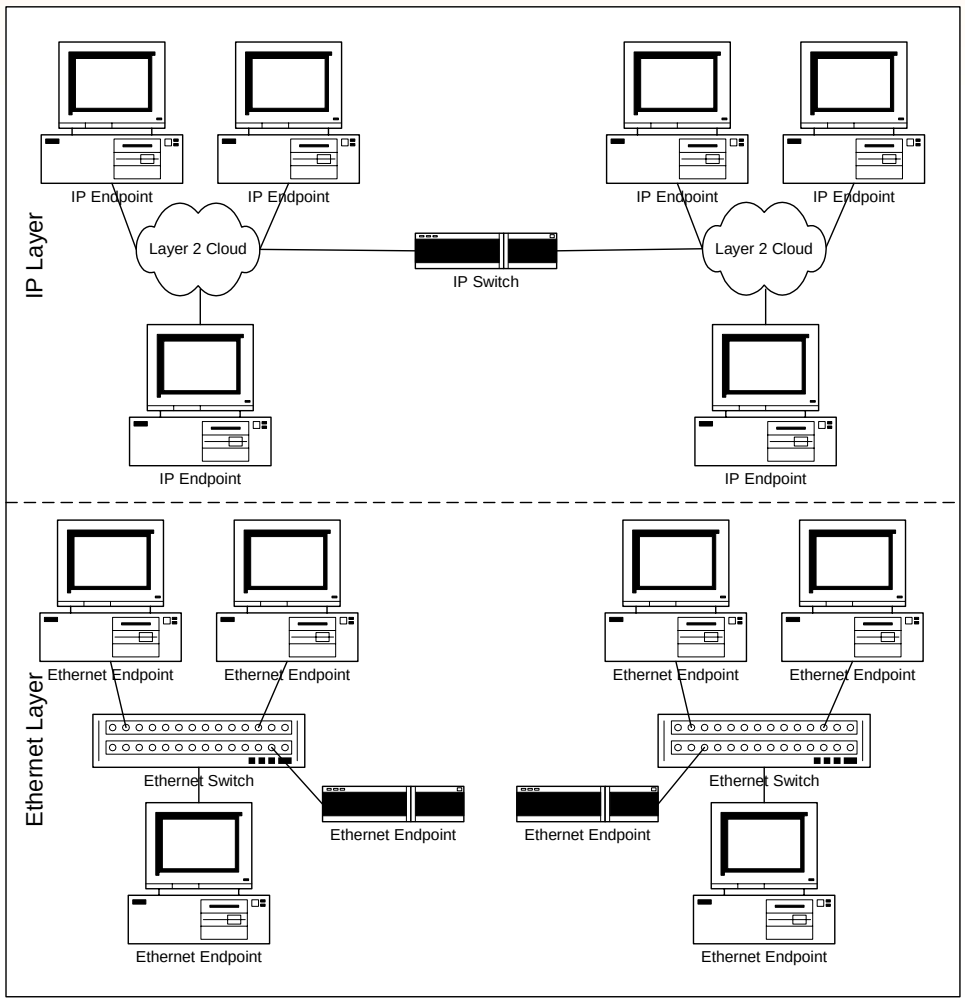
So, what is a layer network?

- Clients of a layer network form another layer network.
  - Server layer resources are used by the client layer to connect client switches together.
  - The boundaries of a client layer network and a server layer network are not the same



So, what is a layer network?

- Another view



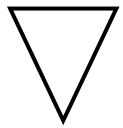
So, what relates layer networks?

- Layer networks are related by the points where information from one layer is adapted to be carried by another layer
  - Ex. IP over Ethernet
    - ARP: Mechanism to relate flows in client/server layer networks
    - Specification of Protocol Number
    - Specification of mapping IP TOS bits into Ethernet Priorities
    - Specification for placing IP packet into Ethernet payload field
  - Ex. IP over ATM
    - ATMARP: Mechanism to relate flows/links in client/server layer networks
    - Specification for placing IP packet into ATM payload field

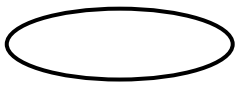
Mechanisms are specific to client and server layer networks being related

Layer network modeling: Data-plane view

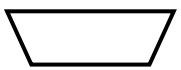
- Diagrammatic convention exists for these functions



Layer network endpoint (a.k.a. Termination Function)



Layer network switch (a.k.a. Connection Function)

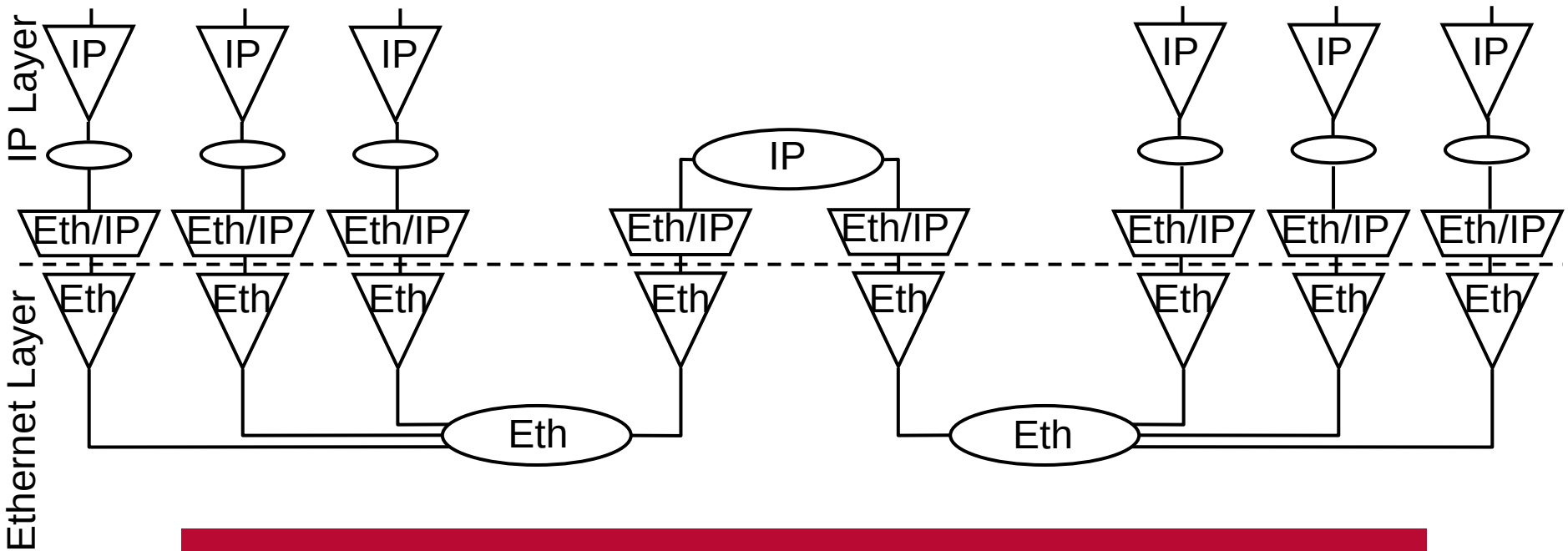


Layer to layer adapting (a.k.a. Adaptation Function)

Functional Modeling is documented in ITU Recommendations G.805 & G.809

Layer network modeling: Data-plane view

- Example use of diagrammatic convention



Model is independent of network element boundaries, supporting any NE structure

Layer Independent Routing

- Routing is performed by each layer independently
  - Each layer maintains view of topology of the layer network instance it is a part of
- Layer network control instances are unaware of each other
- Topology consists of:
  - Nodes: endpoints/switches
  - Arcs: links connecting switches
- Need a way to represent potential connectivity provided by the server layer
  - Use mechanism similar to pseudo-node used by OSPF/IS-IS
    - Models NBMA/Ethernet server-layer as a client-layer switch
    - Topology representation is as a node

Layer Cooperative Routing

- Layer cooperative
  - Routing is performed by a single control instance that has view of both client and server layer topologies
  - Single control instance needs to understand the relationship of points in the client and server layer topologies
  - Resulting routing topology looks very similar to data-plane layer-network model
- Topology consists of:
  - Nodes: endpoints/switches
  - Arcs: links connecting switches
- Need a way to model adaptations
  - Treat as a property of a link (i.e. push/pop layer when traversing link)

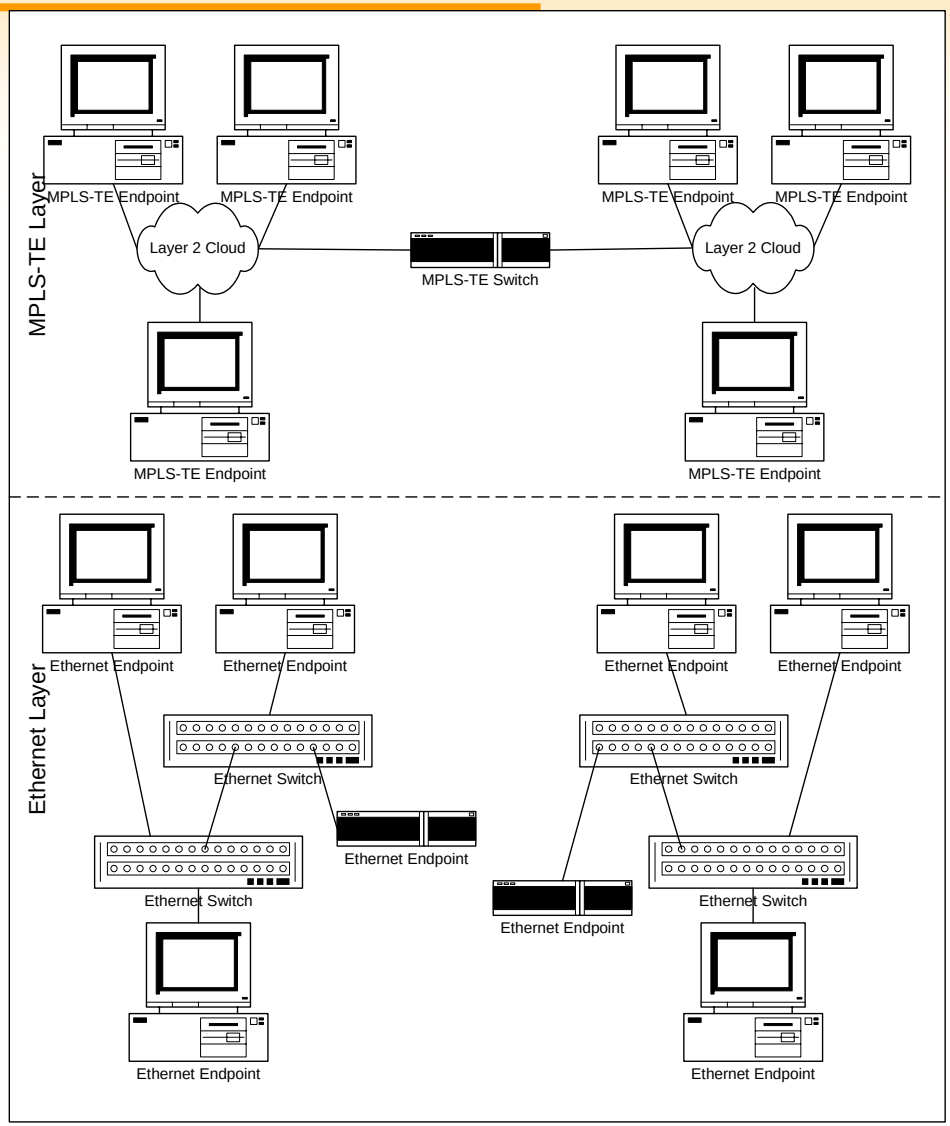
Which approach is better?

- Layer Independent is unaware of server-layer topology
  - Less information – simpler path computations possible
  - Allows client-layer to be unaware of server-layer protocol details
- Layer Dependent develops more optimal paths but requires knowing both client and server layer information
  - May not be acceptable given business relationship between client and server layer networks
- Both may be used between different layer networks
  - MPLS-TE/Ethernet may use layer independent while MPLS-TE/SDH uses layer cooperative

Best approach is dependent on business conditions and equipment capability

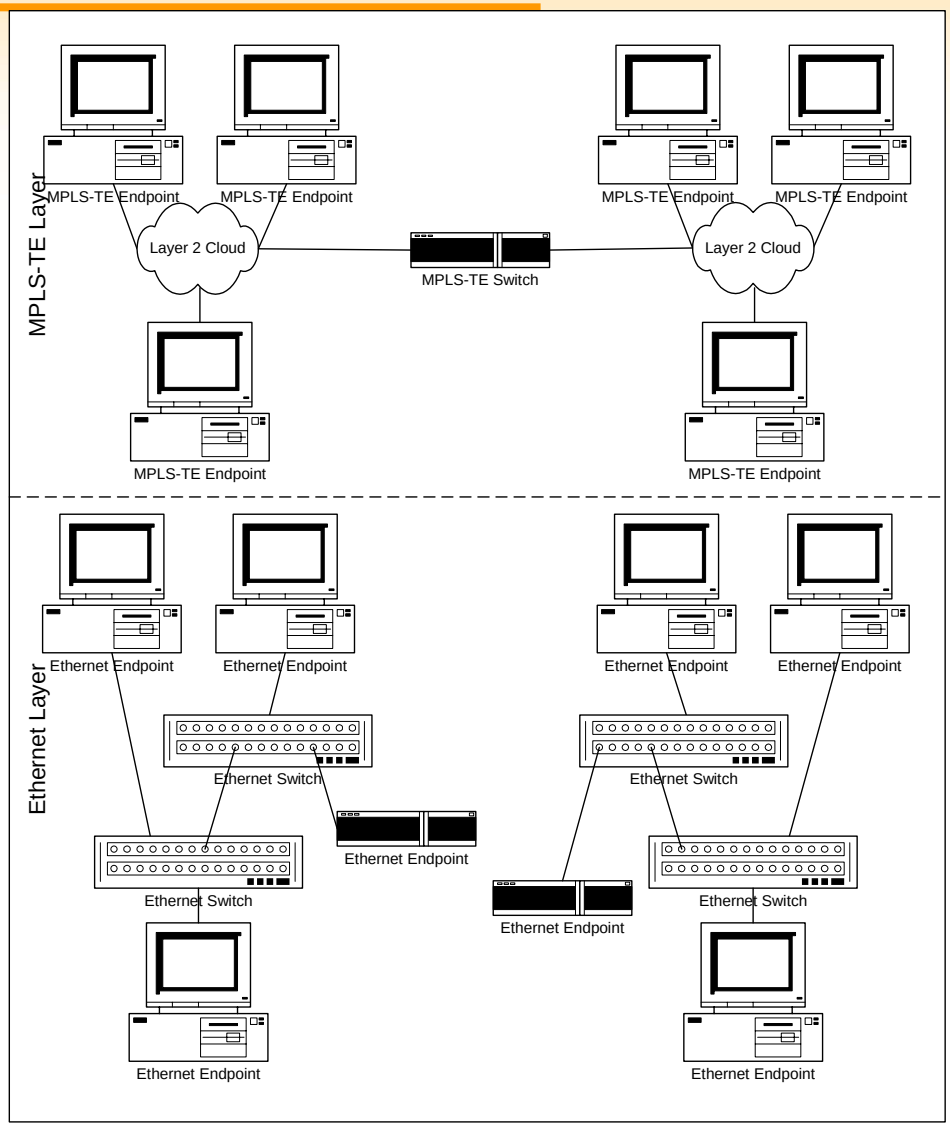
Application of methods

- All examples are based on the MPLS-TE/Ethernet topology shown on the right



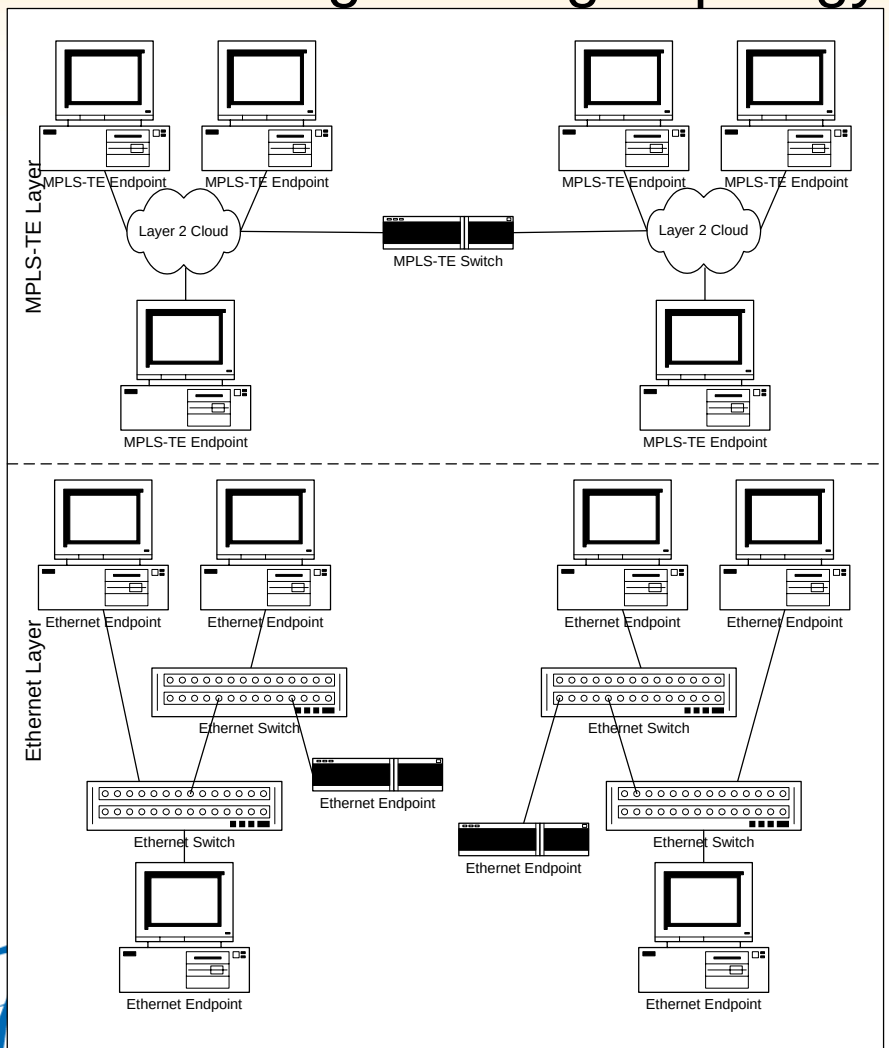
Layer Independent Routing

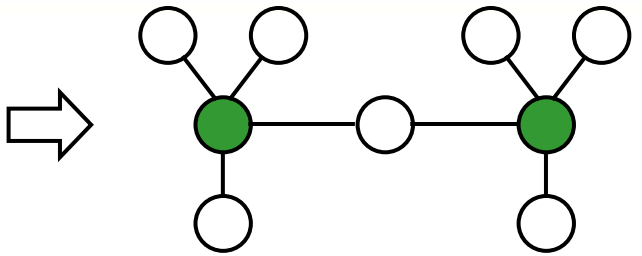
- MPLS-TE Routing protocols (e.g. OSPF-TE/ISIS-TE) used for MPLS-TE network routing
- Ethernet “routing” protocols (e.g. MAC learning, STP) used for Ethernet network routing
- OSPF IP Network LSA / IS-IS Pseudonode represents potential connectivity provided by Ethernet layer



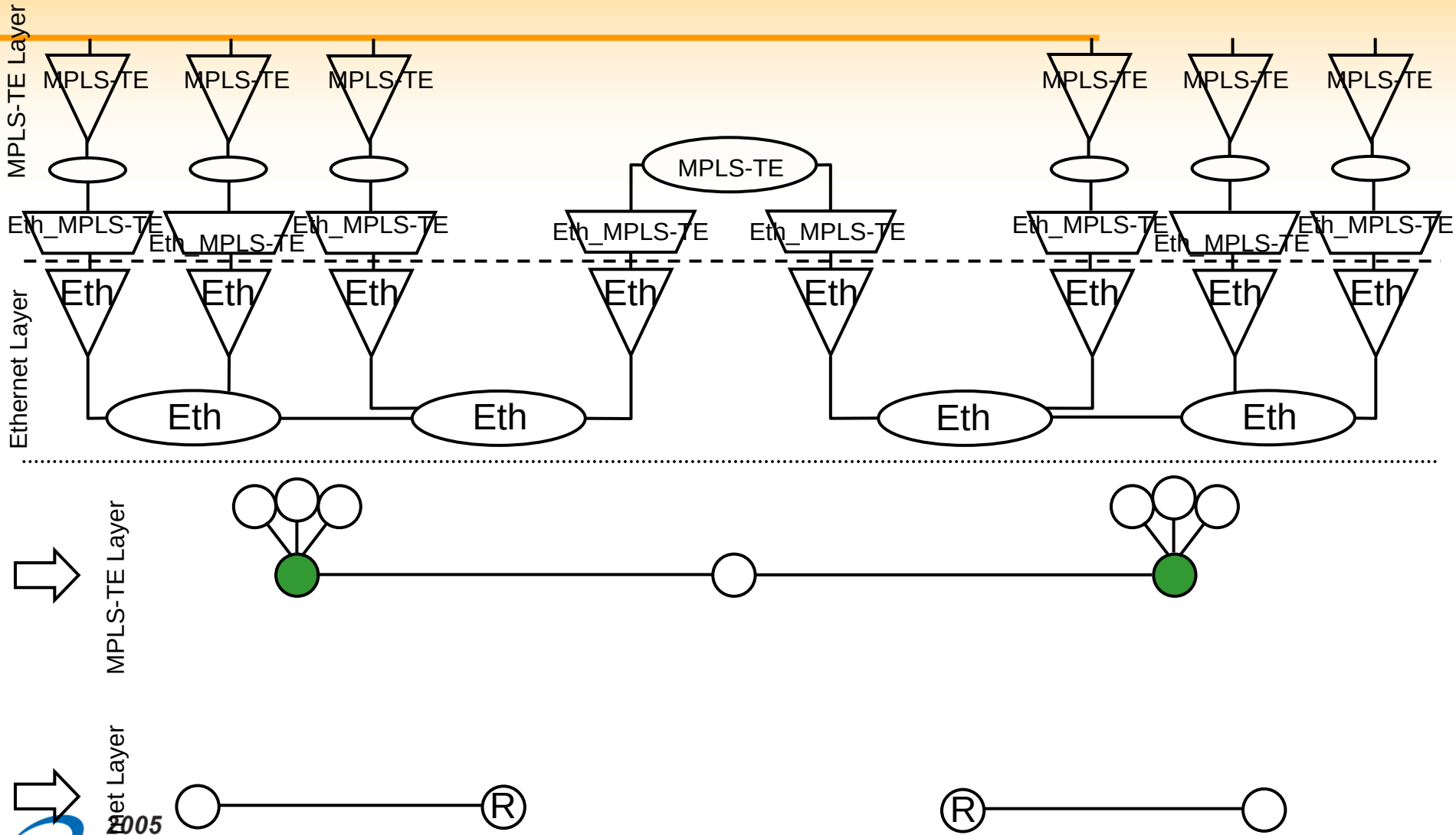
Layer Independent Routing

- Resulting Routing Topology



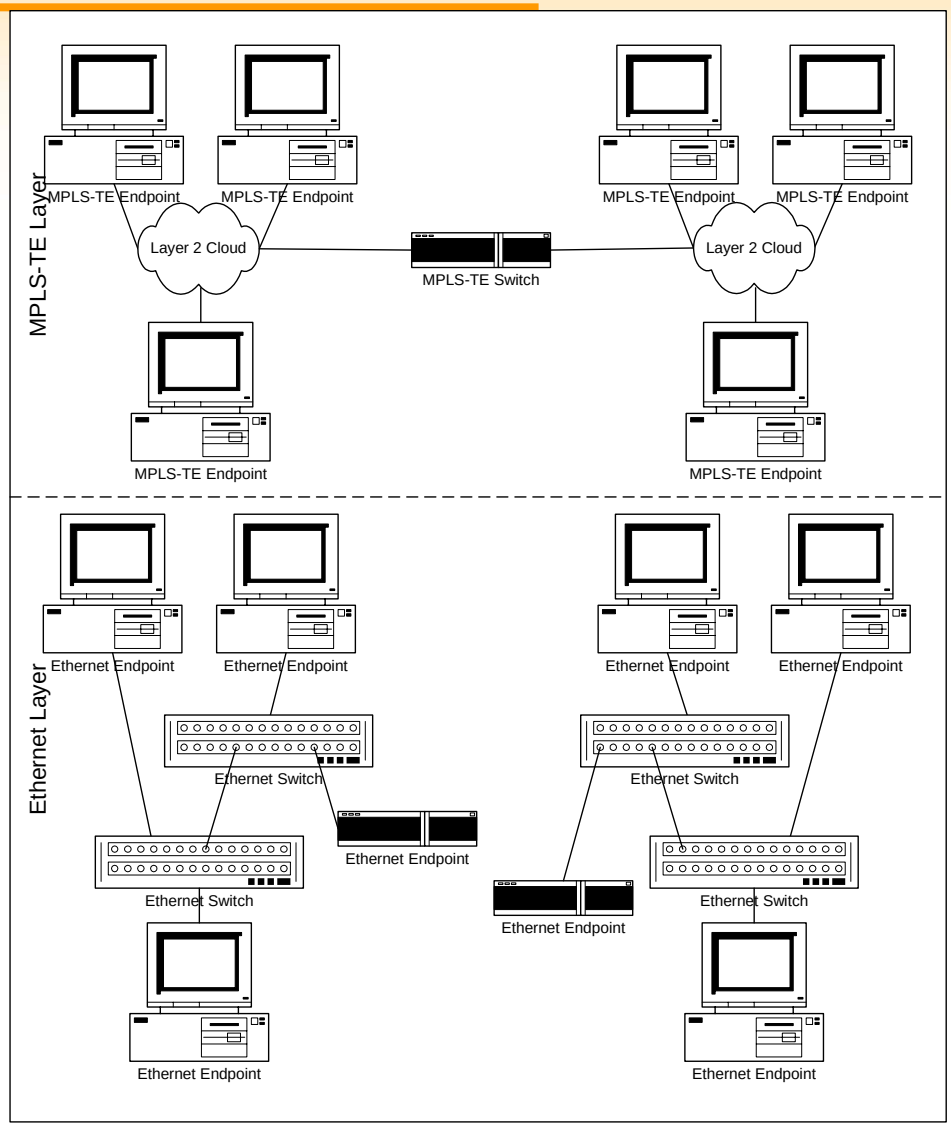


Layer Independent Routing



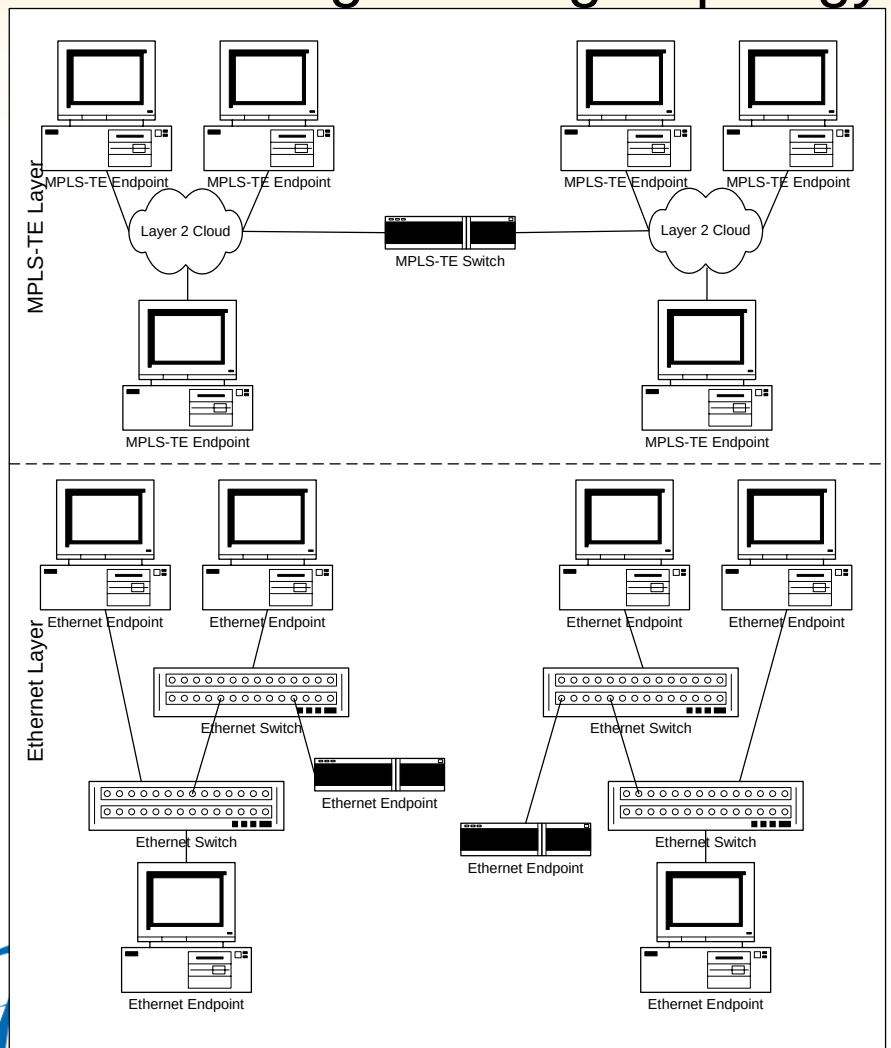
Layer Cooperative Routing

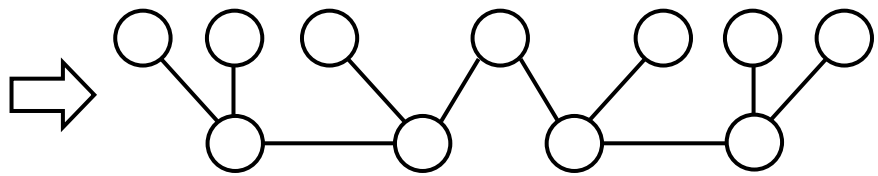
– MPLS-TE Routing protocols (e.g. OSPF-TE/ISIS-TE) used for MPLS-TE and Ethernet network routing



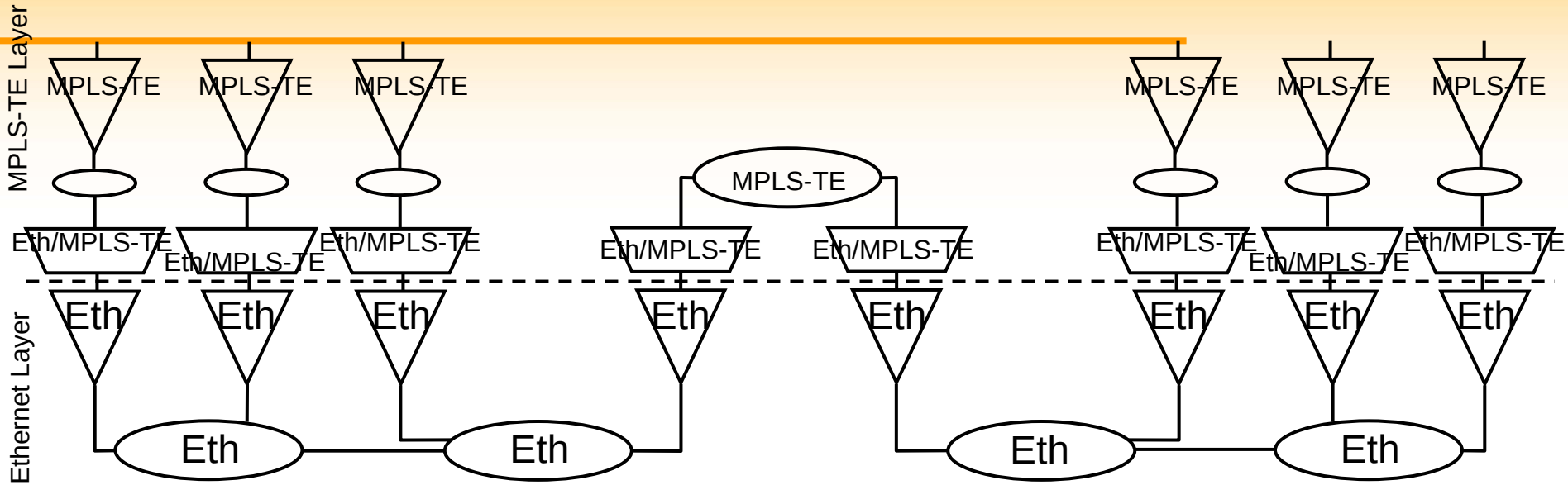
Layer Cooperative Routing

- Resulting Routing Topology

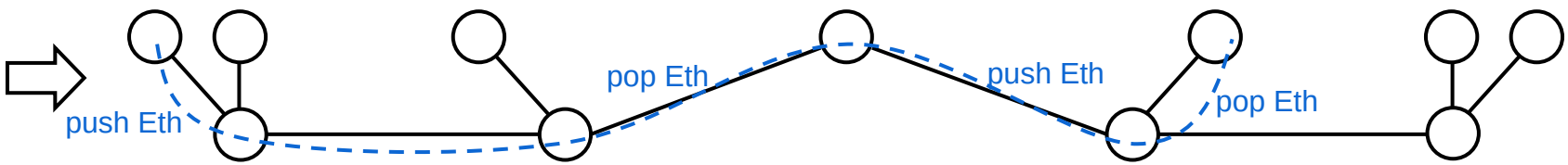




Layer Cooperative Routing



MPLS-TE route calculation:



Summary

- Multi-layer routing is the next step for the MPLS-based control plane
  - Current technology dependent on pre-allocated resources
  - Allows resources in another layer network to be used to support a client-layer connection
- Two approaches exist
  - Layer Independent & Layer Cooperative
  - Approach used is dependent on business conditions and equipment capability
- The methods described in this presentation are technology independent
  - Based on ITU Functional Modeling (G.805 & G.809)
  - Can be utilized regardless of network topology & NE