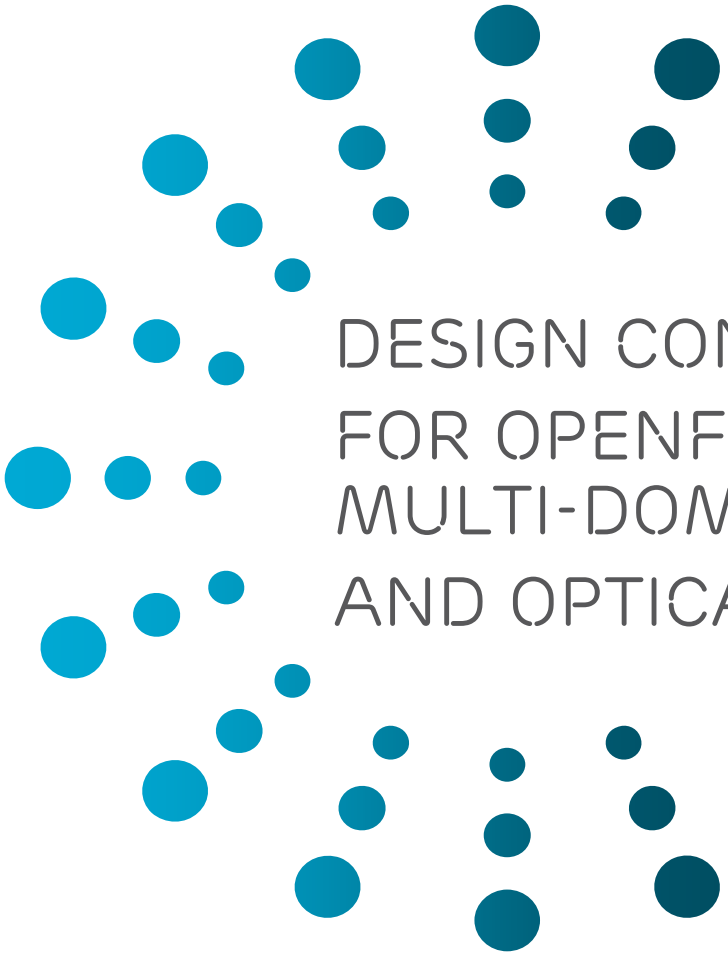

DESIGN CONSIDERATIONS FOR OPENFLOW EXTENSIONS TOWARDS MULTI-DOMAIN, MULTI-LAYER, AND OPTICAL NETWORKS

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ECOC2011 WORKSHOP ON
OPENFLOW EXTENSIONS TOWARDS MULTI-LAYER AND MULTI-DOMAIN NETWORKS: OFELIA

WHY THIS TALK?

- To present one of the approaches investigated by Ericsson Research on how to extend OpenFlow to support multi-layer/multi-technology switches

- To welcome feedback and discuss with other groups present today, who perhaps are investigating different approaches

OUTLINE

1. INTRODUCTION

2. CONTROL PLANE

3. OPENFLOW MULTI-LAYER/MULTI-REGION EXTENSIONS

1. INTRODUCTION

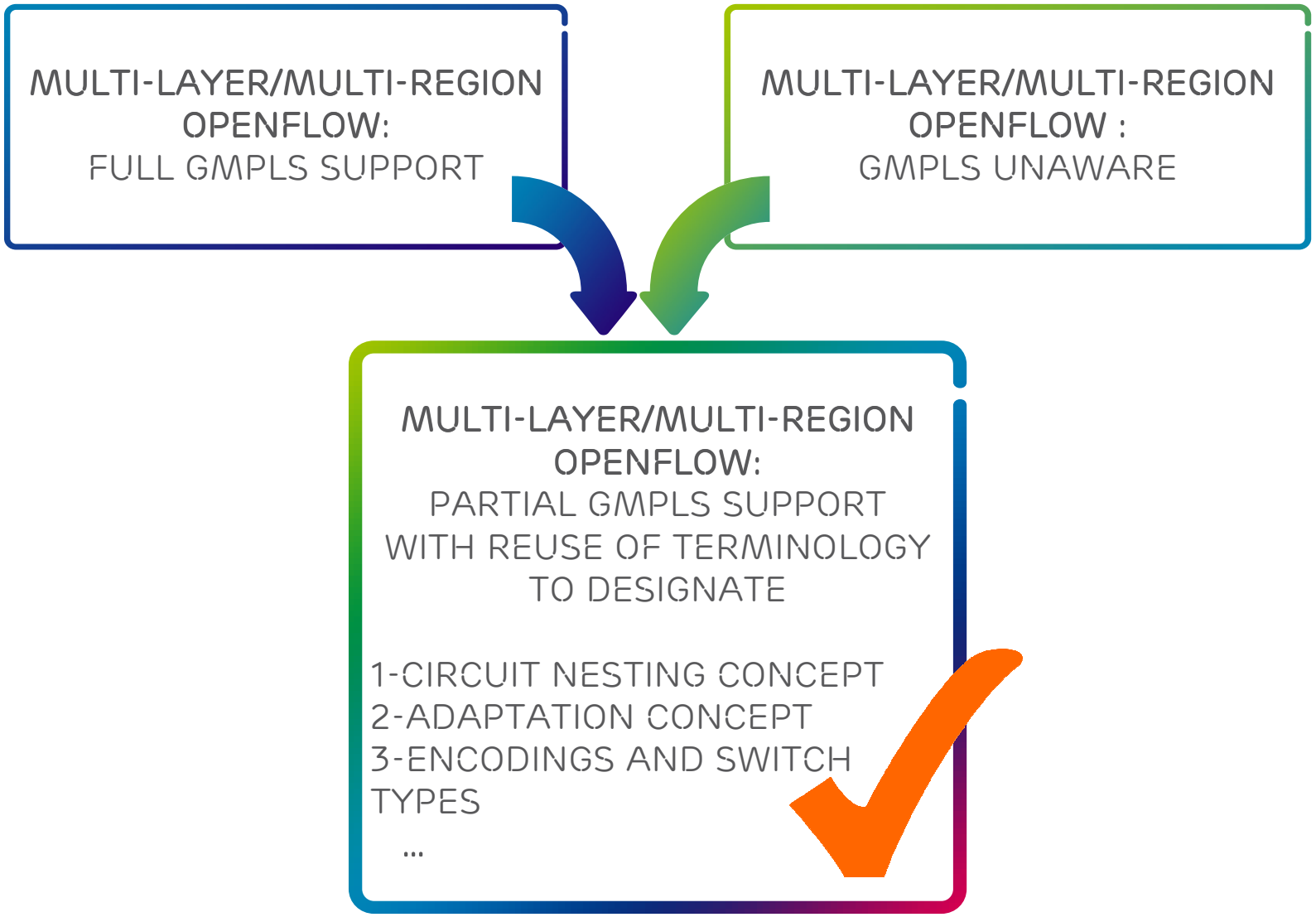
SCOPE

- The presentation covers
  - the components and the basic functionalities of a multi-layer/multi-region optical (WDM) switch;
  - the OpenFlow protocol extensions required to manage it from a remote controller.
- Main starting point references were:
  - CCAMP Working Group, Common Control and Measurement Plane (CCAMP)
  - Stanford studies on "Extensions to OpenFlow Protocol in Support Circuit Switching" (S. Das)
  - Outcomes of Ericsson long term studies and solutions on Packet Optical Integration

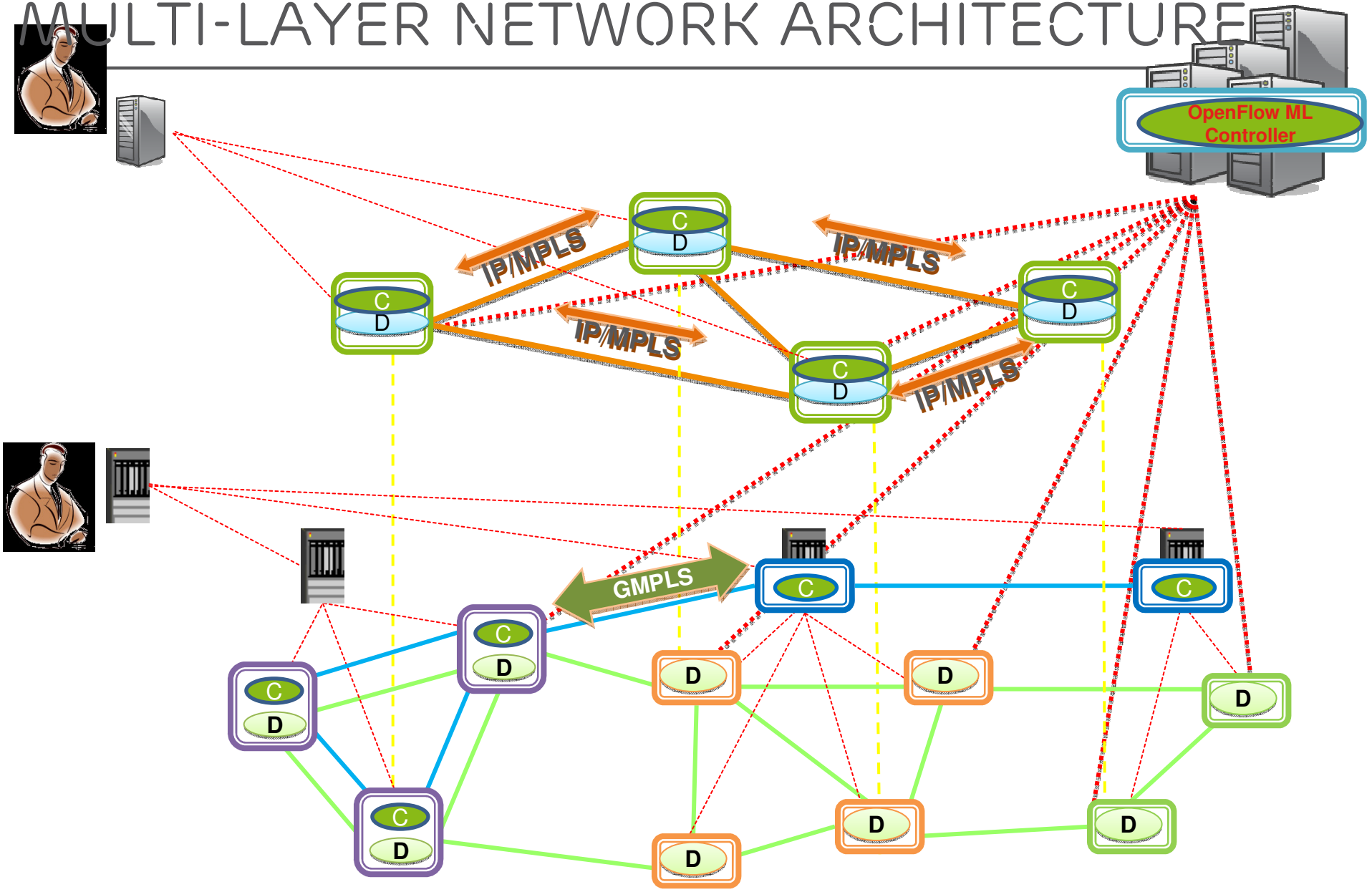
OBJECTIVE: PACKET OPTICAL INTEGRATION

- Benefits of OpenFlow for Split Architecture have been proven.
- Why we need extensions for ML/MR now?
  - Because the current transport networks (mainly based on SONET/SDH) tend to be too slow to react dynamically to router traffic shifts
  - Packet optical integration is a cost effective practice that will allow the packet based routers and switches to operate jointly with the optical network elements.

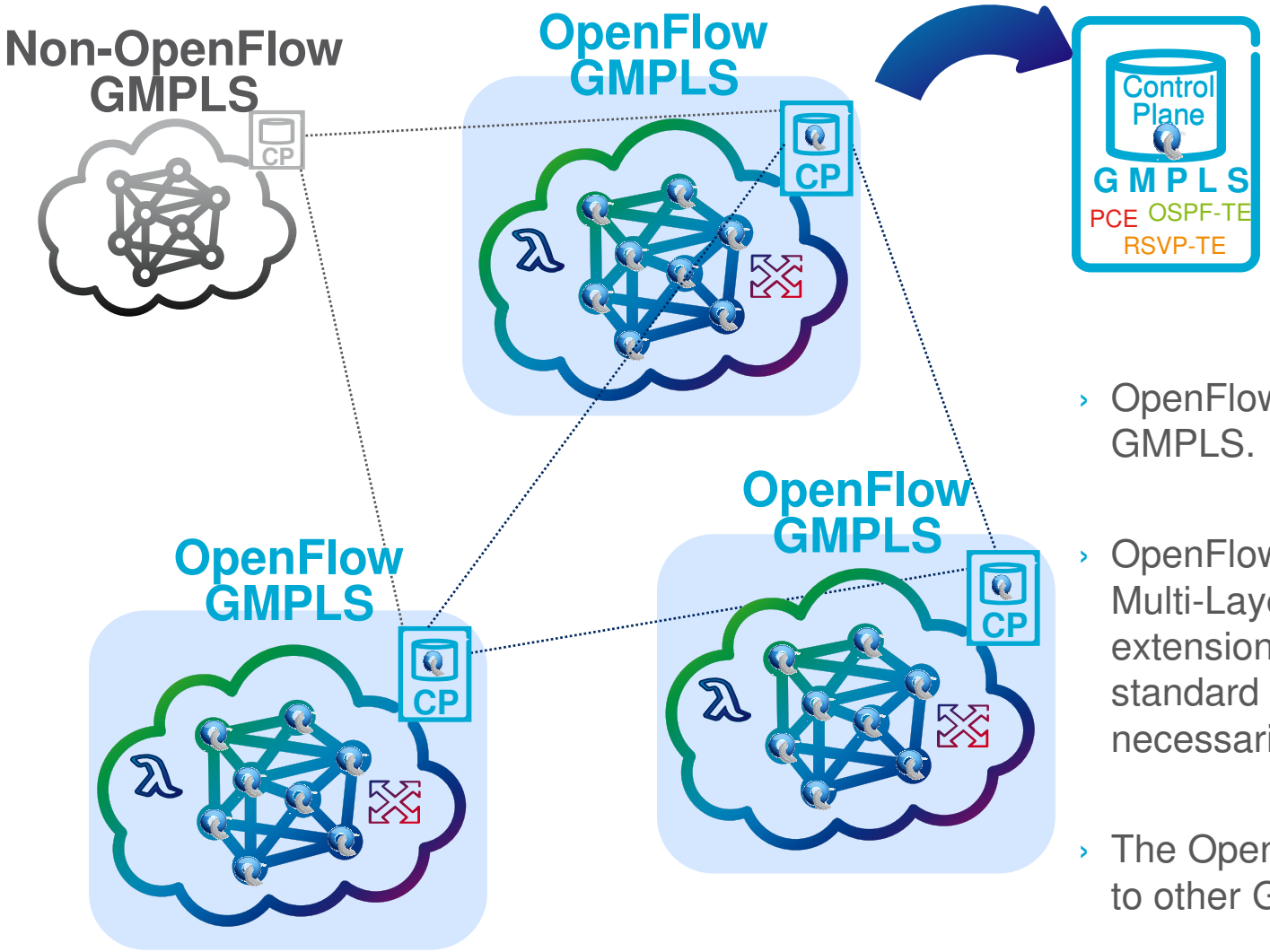
PACKET OPTICAL INTEGRATION POSSIBILITIES WITH OPENFLOW



TRADITIONAL VERSUS OPENFLOW BASED MULTI-LAYER NETWORK ARCHITECTURE



DESIGN USE CASE SCENARIO

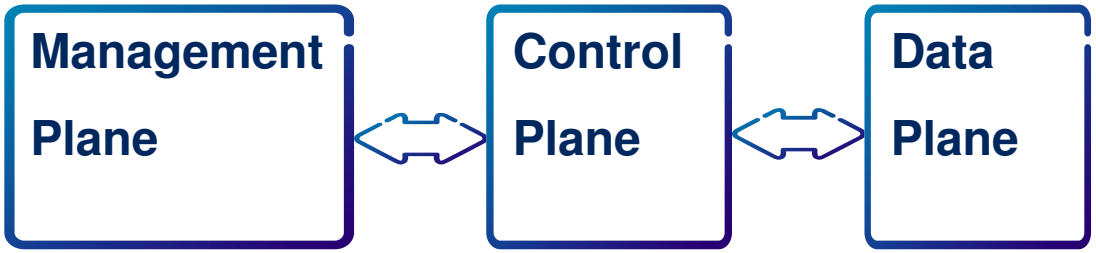


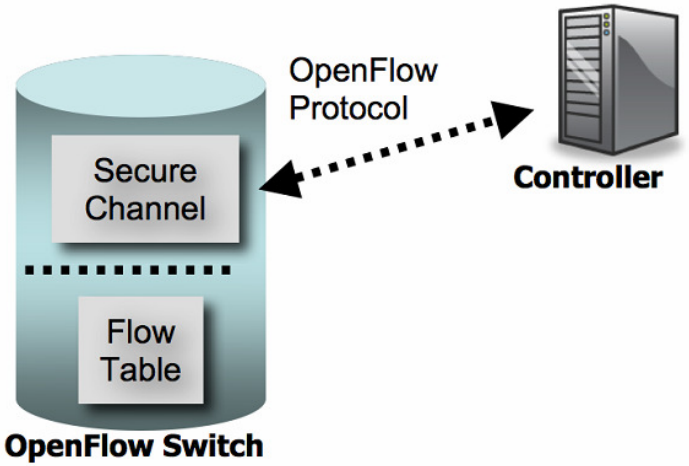
- OpenFlow Controller supports GMPLS.
- OpenFlow cloud implements Multi-Layer and Optical extensions by following GMPLS standard encodings but not necessarily the routing protocols
- The OpenFlow controller can talk to other GMPLS control planes

2. CONTROL PLANE

OPENFLOW BASED CONTROL PLANE

- OpenFlow control plane:
  - a transport layer (layer 4) secure channel to connect the node to its controller (to control and manage the node)
  - inside the node, the interface between the data plane and this channel is implementation specific





MULTI-LAYER/MULTI-REGION CONTROLLERS

References: RFC3471 , RFC3945 , RFC4397 , RFC5212 , RFC5339 and RFC6001 .

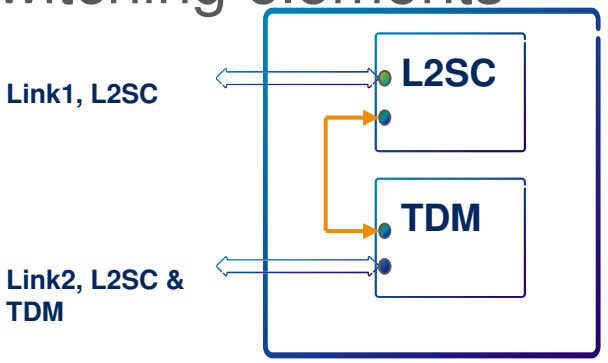
- **Region** refers to switching technologies (e.g. PSC or TDM)
- **Layer** refers to granularities inside a switching region. (e.g. in TDM, an OC12 or a VC12 are layers)
- The interfaces on a GMPLS router or node can have one or many of the minimum six standard switch types:

  The interface can be

  1. **Packet switch capable (PSC),**
  2. **Layer 2 switch capable (L2SC),**
  3. **Time division multiplex capable (TDM),**
  4. **Lambda switch capable (LSC) or**
  5. **Fiber switch capable (FSC).**
  6. **RFC6002 defines a sixth region for port switching called data channel switch capable (DCSC)**

MULTI-LAYER/MULTI-REGION CONTROLLERS (CONT.)

- A node can have a single or multiple switching type capabilities (Multi-Region node)
- Nodes with multiple switching type capabilities are further categorized as *simplex* or *hybrid*
- This Hybrid is not to be confused with *OpenFlow-Hybrid* switches which support both OpenFlow and non-OpenFlow pipelines
- The nodes that have at least one interface that supports more than one switching capability are called hybrid nodes
- A hybrid node has thus more than one switching elements (matrices) interconnected internally:



MULTI-LAYER/MULTI-REGION CONTROLLERS (CONT.)

- The **Interface switching capability (ISC)** is the interface's ability to forward data of a particular data plane technology (one of the six regions)
- Internal links connecting the switching matrices in hybrid switches have **finite capacities**
- This adjustment capacity information is critical for path computation
- This adjustment capacity information is available in the **ISC descriptor (ISCD),** advertised by routing protocols for each link
- Because, when link bundling is performed ..this information is lost.
  - and RFC6001 proposes the IACD extensions for GMPLS signaling

GMPLS ENCODINGS

- GMPLS general label format encoding RFC3471:

8 bits	8 bits	16 bits
Encoding	*Switch Type*	*General Payload ID*

- GMPLS TDM label format encoding RFC4606:

16 bits	4 bits	4 bits	4 bits	4 bits
S	*U*	*K*	*L*	*M*

	SONET	SDH
S=1→N	-N>1, S=0 for STS-1 -Index of STS-3 inside an STS-3N	-N>0, S=0 for STM-0 -Index of AUG-1 inside an STM-N
U=1→3	-N>1, U=0 for STS-1 (only significant for STS-3N) -Index of a particular STS-1 SPE within an STS-3	-N>0, U=0 for STM-0 -Index of a particular VC-3 within an AUG-1
K=1→3 (TUG-3)		-Is the index of a particular TUG-3 within a VC-4
L=1→7 **(TUG-2)**	-Is the index of a particular VTG within an STS-1 SPE	-Is the index of a particular TUG-2 within an TUG-3 or VC-3
M=1→9 (SONET) **M=3→9 (SDH)**	-Index of a particular VT1.5_SPE, VT2_SPE, or VT3 SPE within a VTG -M=1->2 indicates a specific VT3 SPE inside the corresponding VTG (VT3 #1 &2) -M=3->5 indicates a specific VT2 SPE inside the corresponding VTG (VT2 #1 to 3) -M=6->9 indicates a specific VT1.5 SPE inside the corresponding VTG (VT1.5 #1 to 4)	-Index of a particular VC-11, VC-12 within a TUG-2 -M=3->5 indicates a specific VC-12 inside the corresponding TUG-2 (VC-12 #1 to 3) -M=6->9 indicates a specific VC-11 inside the corresponding TUG-2 (VC-11 #1 to 4)

GMPLS ENCODINGS (CONT.)

- GMPLS WDM label format encoding RFC6205:

3 bits	4 bits	9 bits	16 bits
Grid	*Ch. Spacing*	*ID*	*n*

Grid	Value
Reserved	0
ITU-T DWDM	1
ITU-T CWDM	2
Future use	3-7

Ch. Spacing (THz)	Value
Reserved	0
0.1	1
0.05	2
0.025	3
0.0125	4
Future use	5-15

Ch. Spacing (nm)	Value
Reserved	0
20	1
Future use	2-15

- 16 bit value *n* as a two's complement integer to compute :
  - **DWDM Frequency (THz) =**
    193.1 THz + n * channel spacing (THz)
  - **CWDM Wavelength (nm) =**
    1471 nm + n * 20 (nm)

The recent revision of ITU-T Recommendation [G.694.1] has decided to introduce the flexible grid DWDM technique which provide a new tool that operators can implement to provide a higher degree of network optimization than fixed grid systems.

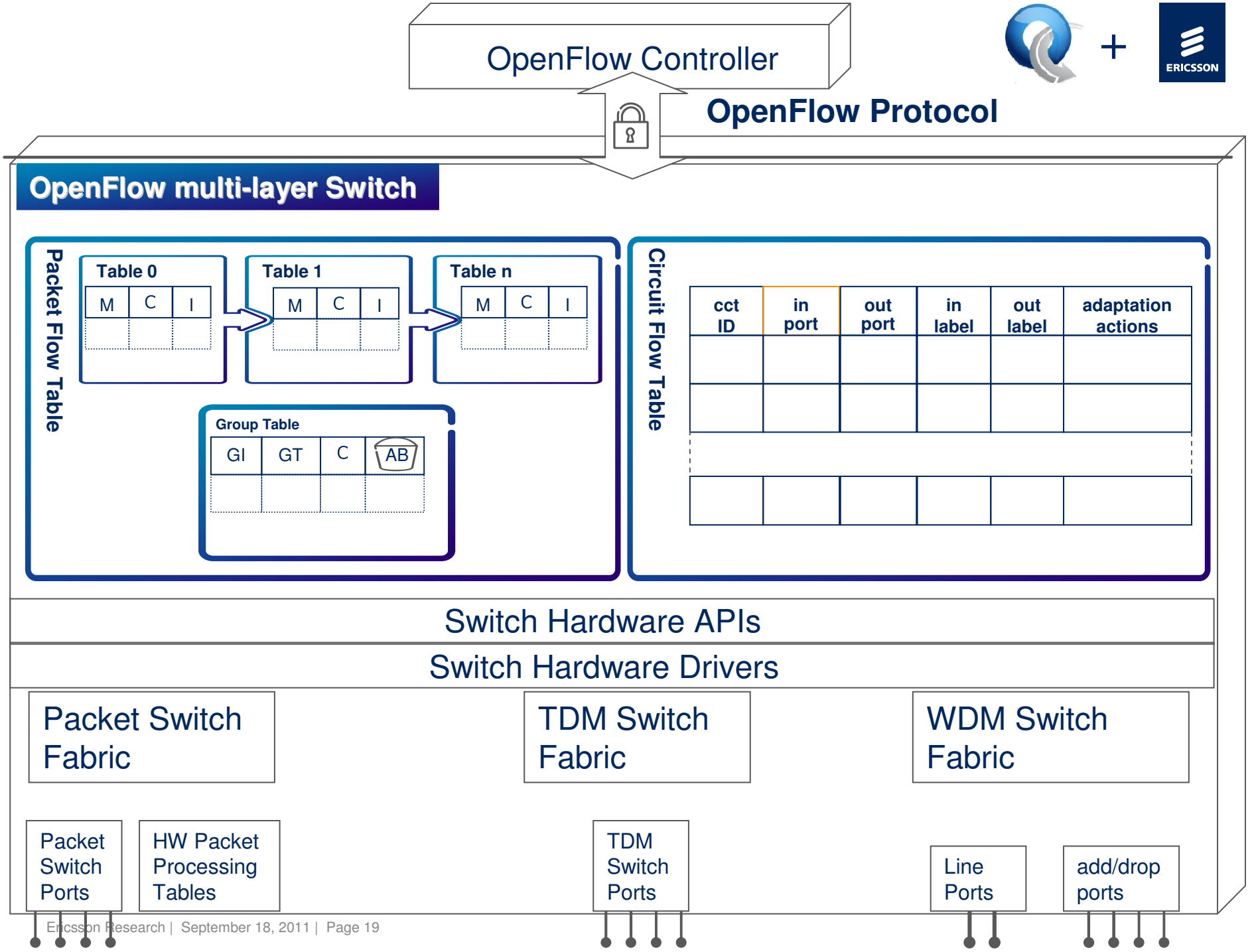
http://tools.ietf.org/html/draft-li-ccamp-flexible-grid-label-00

3. OPENFLOW MULTI-LAYER/MULTI-REGION EXTENSIONS

NEEDED EXTENSIONS

- Fundamental difference between circuit switched and packet switched OpenFlow:
  - the flow table is not used to *lookup* circuit flows
  - OpenFlow controller only responsible for setting up the cross-connections in the switch (OpenFlow protocol to establish circuits and receive stats messages from the switch)
  - cross-connections established in a *proactive* way.

- Possibility: a packet sent to the controller can trigger the establishment of a new circuit cross-connect (or pre-configured cross-connects, similar to virtual TE-links in GMPLS).


OpenFlow Controller
+
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OpenFlow Protocol
OpenFlow multi-layer Switch
Packet Flow Table
Table 0
M
C
I
Table 1
M
C
I
Table n
M
C
I
Group Table
GI
GT
C
AB
Circuit Flow Table
cct ID
in port
out port
in label
out label
adaptation actions
Switch Hardware APIs
Switch Hardware Drivers
Packet Switch Fabric
TDM Switch Fabric
WDM Switch Fabric
Packet Switch Ports
HW Packet Processing Tables
TDM Switch Ports
Line Ports
add/drop ports

EXAMPLE EXTENSIONS

- New circuit IDs serve as virtual ports to other flows
- Circuit IDs are virtual ports to which incoming packet flows can be forwarded
- Other circuit flows can also point to a circuit ID, and hence represent a circuit hierarchy (the equivalent to GMPLS LSP nesting)
- Since the circuit flows do not affect the *on the fly* processing of packets, they can be implemented in software

EXAMPLE EXTENSIONS (CONT.)

- Circuit flow entry:

CCT ID	*in port*	*out port*	*label in* *(e.g. encoding,ST,G-PID)*	*label out* *(e.g. encoding,ST,G-PID)*	*adaptation actions*

- Circuit Identifier (CCT ID):
  - a 32 bit unsigned integer representing the circuit flow-virtual port
- In Port/Out Port:
  - a 32 bit unsigned integer representing the incoming/outgoing port.
- In Label/Out Label:
  - a 32 bit unsigned integer representing the incoming/outgoing signal
  - the general way is to specify the encoding, switch type and payload ID (using GMPLS standard encodings as presented before)
- No adaptation standardized with GMPLS yet - OpenFlow actions used de specify different adaptations

NEXT STEPS

- The extensions need to be fine tuned and precisely specified : implementation to be completed before the end of the year
- OpenFlow 1.1 has been considered. The extensions may have to be remapped to new ONF architectural guidelines

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