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ConSION: Control & Signaling Intelligence Overlay Networks for Optical Networking

1 Status of this Memo

2 Abstract

When one extrapolates from the ongoing evolutionary trends of IP router / switch development and its role in the build-out of optical core, edge, access and enterprise networks, it is reasonable to reach the almost inescapable conclusion that within a few years, there will be a complete physical separation of the commercial equipment embodying various concerns, aspects, roles and functions of data communications, Namely,

1. Separate equipment for transport (transmission, switching and multiplexing) and traffic forwarding.

2. Separate equipment concerned with control, signaling, traffic engineering, provisioning, protection and restoration control, as well as, traffic and flow management, (generalized "softswitches").

3. Separate equipment for network management, operations support, measurement & metering, OAMP, inter-OSS, engineering management (including performance management, availability management, security management, accounting management), as well as life cycle support.

In essence, the prediction is that the future optical network infrastructure is likely to be made up of at least four physically

separate and distinct but inter-connected overlay networks, variously concerned with a) Transport and Traffic Forwarding, b) Control and Signaling, c) Management & Administration, and d) Service Engineering Support.

The CoSION proposal is that the transport/forwarding, control/signaling, and management/service engineering "planes" of optical networking ought to be designed, implemented, embodied and deployed in four physically separate (but co-joined) overlay networks. Furthermore, the design of supporting protocols ought to explicitly take into account in their specifications, this physical separation of aspects and roles. Also, the protocol engineering and designs should be fashioned in way that allows the four networks to evolve semi-autonomously. This can be achieved by defining and supporting open interfaces between and within the various overlay networks.

Commercially, different equipment suppliers and vendors are likely to be interested in producing network elements for the four overlay network types.

This report proposes that this outcome of physical separation of aspects and roles be explicitly acknowledged and taken into account within the IETF in the future evolution of the MPLS and GMPLS protocol suites, as well as those of other protocol suites for control, traffic engineering, management and measurement that will constitute the core of the Control and Signaling overlay networks for optically-based next generation networks.

The most direct impact on the protocol engineering in the IETF will be a re-packaging via a careful separation of aspects of protocols in some existing protocol suites, (such as MPLS, GMPLS), into well-defined and standardized open interfaces. All these protocols are concerned with transport/forwarding support, management & administration support and "true" control and signaling and feedback. This will then be followed by future protocol extensions in each overlay network plane.

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4 Introduction

We start with a definition of an acronym that helps to explain the essence of the ConSION proposal.

SOCAR stands for Separation Of Concerns, Aspects and Roles. Now that it has been given a pronounceable acronym, it is clear that the SOCAR principle has indeed been applied numerous times in communications protocol design and engineering in the IETF and other bodies.

The most familiar examples of its application include the protocol "layer" concept in the OSI 7-layer model and the related layering concepts in other protocol suites such as TCP/IP, SNA, DECnet, WAP, etc. Over the years, several groups have found it necessary to introduce "sub-layers" and "shim" layers such as those for SNAP/LLC and for G/MPLS [RFC3031], [RFC3034], [RFC3035], [RFC3036], [GMPLSx01], [GMPLSx02].

The Broadband-ISDN and ATM community expanded this layer separation by introducing the concept of protocol "planes" orthogonal to the layers. Thus, one can talk about the User/Data plane (U-plane), the Control plane (C-plane) and the Management plane (M-plane). The protocol layers and the planes together form a matrix space.

All of the above applications of the SOCAR principle are to be considered the use of "logical" SOCAR in that each is focused on the conceptual and abstract separation of aspects, roles and functions in data communications.

There is a related, but less familiar concept called "physical" SOCAR. It is physical SOCAR that is being advocated by the ConSION proposal to be systematically applied to future protocol suites development, particularly for intelligent optical networks (I.O.N.).

Physical SOCAR states that aspects, roles and functions that are logically separated can be and should also be embodied and implemented in physically separate network elements, variously termed engines, servers, gateways, devices and units. Furthermore, it should be acknowledged from the start that different vendors and manufacturers can supply these physically separate devices. Therefore, the physically separate embodiment and the potential multi-vendor situation should be explicitly taken into account in the protocol engineering. In particular, open interfaces should be specified at SOCAR separation boundaries.

One example of the application of the physical SOCAR principle in protocol engineering is the SS7 standard for common channel signaling (CCS)[ITUQ7xx]. The POTS/PSTN/ISDN network is physically separate from the controlling signaling network (the SS7 network). A second example is the ongoing work on Softswitch for the convergence of traditional POTS/Voice with the newer VOIP / Internet telephony [SOFTSWCH]. The media gateways are physically separate from the media gateway controllers, together with open protocol suites being defined for the interface between them (for example, SIP [RFC2543], Megaco/MGCP [RFC2805], [RFC3015] or H.248/H.323).

Optical networking will play very significant roles in the development, deployment, operation and management of next generation data communication networks and infrastructures. Already the logical SOCAR principle has started to be applied to the specification of these networks. An example is the ASON (Automatic Switched Optical Networks) concept [ASONx01] that logically separates the O.N architecture into the Transport/Forwarding (T&F) plane, Control & Signaling (C&S) plane, and the Management & Administration (M&A) plane.

The ConSION proposal advocates that the physical SOCAR principle should also be applied systematically to the future development of protocol suites for I.O.N.

According to the ConSION concept, the logical separation planes advocated by the ASON model should also be extended in the following manner. Its logical planes will be implemented as physically separate (but interconnected) overlay networks.

Therefore, the CoSION model recognizes at least four overlay networks that together constitute a next generation I.O.N.:

1. Transport & Forwarding (T&F) Overlay Network.
2. Control & Signaling (C&S) Overlay Network.
3. Management & Administration (M&A) Overlay Network.
4. Service Engineering (S&E) Overlay Network.

5 ConSION Architectural Model

The choice that there are only four overlay networks in the ConSION proposal is completely arbitrary, but it is both necessary and sufficient for the development a set of protocol suites for intelligently controlled, next generation optical networks and infrastructures.

Furthermore, the ConSION proposal advocates that open interfaces should be defined between each pair of the overlay networks, together with the specification of open protocol suites that implement these interfaces.

Figure 1 shows at a high level, the collection of inter-overlay network open interfaces that need to be defined and specified as protocol suites (TF<---->CS, TF<---->MA, TF<---->SE, CS<---->MA, CS<---->SE and MA<---->SE). These open interfaces are labeled In.TF.CS, In.TF.MA, In.TF.SE, In.CS.MA, In.CS.SE and In.MA.SE, respectively. The prefix In stands for interface or "intelligence".

```
                +----------+                 +----------+
                |          |                 |          |
                |   MA     |     In.MA.SE    |    SE    |
                |  Overlay |<--------------->| Overlay  |
                |  Network |                 | Network  |
                |          |                 |          |
                |          |       +-------->|          |
                +----------+       |         +----------+
                  ^  ^             |                  ^
                  |  |             |  In.CS.SE        |
                  |  |  In.CS.MA   |                  |
                  |  |             v                  |
                  |  |       +-------------+          |
                  |  |       |             |          |  In.TF.SE
                  |  |       |             |          |
                  |  +------>|     CS      |          |
                  |          |   Overlay   |          |
      In.TF.MA    |          |   Network   |          |
                  |          |             |          |
                  |          |             |          |
                  |          +-------------+          |
                  |                ^                  |
                  |                |                  |
                  |                |  In.TF.CS        |
                  |                |                  |
                  v                v                  v
                +---------------------------------------+
                |                                       |
                |                                       |
                |        TF Overlay Network             |
                |                                       |
                |                                       |
                |                                       |
                +---------------------------------------+
```

Figure [1]: ConSION Architectural Model

In a graybox approach (in contrast to a blackbox or a whitebox approach), the proposal also advocates that open interfaces should be specified between (some) of the network elements and components inside each overlay network. These intra-overlay network interfaces (endo-interfaces) can be labeled: In.TF.TF, In.CS.CS, In.MA.MA and In.SE.SE.

This systematic use of open interfaces will allow different vendors to produce network elements for different overlay networks and for the different parts of the overlay networks.

One implication for IETF protocol engineering is that open
interfaces and associated protocol suites should be specified so
that IP forwarding can physically separated from IP control &

signaling (mainly route calculations by routing protocols). Similarly, G/MPLS forwarding should be allowed to become physically separate from G/MPLS control & signaling. Currently, all these aspects and roles are inter-mixed and conflated in the protocol proposals, specifications and documents from IETF and the other bodies.

At another more detailed level, it should be explicitly recognized and accommodated (in the protocol engineering efforts) that each overlay network is actually an internet (an infrastructure consisting of a network of networks.) More importantly, the governing principle is that in actual operational deployment, each overlay network will be partitioned or tessellated into separate Administrative Domains (AD). The AD-networks are then co-joined via bilateral peering and/or via inter-exchange or inter-connect points (called inter-AD domains). Examples of inter-AD domains include NAPs, MAEs, ISP IXs and carrier hotels.

Of course the principle of segmentation by AD domains is well recognized in the IETF community and has been applied to great effect in the definition of IGP (intra-domain) and EGP (inter-domain) routing protocols such as OSPF [RFC2328] and BGP4 [RFC1771]. The ConSION proposal is merely advocating that the principle be adopted and systematically applied in all future development of protocol suites that are meant to control and manage optically-based networking infrastructures.

Therefore, in the spirit of applying the physical SOCAR within each overlay network (In.TF.TF, In.CS.CS, In.MA.MA and In.SE.SE), open interfaces and accompanying protocol suites are required for all of the following cases. For each overlay network,

1. Open interfaces between network elements belonging to the same AD in the overlay network (ADi.NE1 <----> ADi.NE2). These are the so-called "private NNIs_. In the CoSION model and architecture, there are four types: private TF.NNI, private CS.NNI, private MA.NNI and private SE.NNI.

2. Open interfaces between network elements belonging to different ADs (or to different inter-ADs) in the overlay network (ADi.NE1 <----> ADj.NE2). These are the so-called "public NNIs_ (network-to-network interfaces). Again in CoSION, there will be four types: public TF.NNI, public CS.NNI, public MA.NNI and public SE.NNI.

3. Open interfaces between network elements belonging to an AD and network elements belonging to an inter-AD in the overlay network: (ADi.NE1 <----> inter-ADk.NE2). These are termed "public" inter-NNI (iNNIs). Again the four types are: public TF.iNNI, public CS.iNNI, public MA.iNNI and public SE.iNNI.

4. Open interfaces between network elements in an AD and network element in an outside, external or "access" (AC) exo-network: (ACj.NE1 <----> ADi.NE2). These are termed (public) _UNIs_ (user-to-

network interfaces), with the following four types: TF.UNI, CS.UNI, MA.UNI and SE.UNI.

In summary, the ConSION model is advocating that all the IETF protocol suites relevant to the deployment, operation and management of optical networking infrastructures be re-organized and re-packaged to explicitly support all of the following open interfaces and their associated collections of protocol suites.

A) Inter-overlay network interfaces

1. In.TF.CS: (TF.ADx.NE1::CS.ADz.NE2).
2. In.TF.MA: (TF.ADx.NE1::MA.ADy.NE3).
3. In.TF.SE: (TF.ADx.NE1::SE.ADw.NE4).
4. In.CS.MA: (CS.ADz.NE2::MA.ADy.NE3).
5. In.CS.SE: (CS.ADz.NE2::SE.ADw.NE4)
6. In.MA.SE: (MA.ADy.NE3::SE.ADw.NE4).

B) Intra-overlay network interfaces

7. In.TF.TF:
   (TF.UNI, public TF.NNI, private TF.NNI, public TF.iNNI)
8. In.CS.CS:
   (CS.UNI, public CS.NNI, private CS.NNI, public CS.iNNI)
9. In.MA.MA:
   (MA.UNI, public MA.NNI, private MA.NNI, public MA.iNNI)
10. In.SE.SE:
   (SE.UNI, public SE.NNI, private SE.NNI, public SE.iNNI)

This protocol "re-engineering" will affect the future efforts of several IETF WGs such as forces, ipo, iporpr, ccamp, mpls, gsmp and the routing protocols WGs.

6 Practical Transport and Forwarding Overlay Networks

The T&F overlay networks to be controlled are expected to be built out of such network elements as Optical cross-connects (OXCs or OCXs); Optical Add-Drop multiplexers (OADMs); Optical switches; Optical gateways and bandwidth managers; Wavelength routers or wavelength switching routers; Optical waveband and fiber-level switches; SONET/SDH (digital) cross-connects (DCS); SONET/SDH Add-Drop multiplexers (ADMs); DWDM transport equipment as well as CWDM and OFDM variants; Free space optics (FSO) equipment; Photonic packet switches (under research and development); multi-service provisioning platforms (MSPPs); Passive Optical Networking (PON) equipment; FTTx equipment (where x stands for Home (H), Curb (C), Building (B)); Broadband access equipment (xDSL, Cable data, Wireless Local Loop (WLL)); ATM switches and Frame Relay switches, Integrated Access Devices (IADs); venerable switches, multiplexers and concentrators for PDH transport; Ethernet switches and hubs (Fast (100MbE), Gigabit (1GbE) and 10Gigabit (10GbE)); Metro-

Ethernet and optical Ethernet (OpE) equipment; IP routers and router switches (Multi-megabit, Gigabit, Terabit and even Petabit routers); MPLS routers or switch routers, etc., etc.

On the surface, the variety of devices that can be devoted to transport and forwarding (T&F) in modern communications networks is bewilderingly staggering. However, there are some organizing principles that can be used to guide the design of the overlay networks that will be used to intelligently control, manage and operate T&F overlay networks.

1. Any viable and practical optical network is likely to include more than just optical "processing" (transmission, switching, multiplexing and routing) network elements. Pure optical networks are likely to be inter-worked and integrated with other infrastructures based on broadband networking, both fixed and mobile wireless networking, as well as the venerable PSTN/ISDN networking.

2. For the purposes of control, signaling, network management, service creation and administration, distinctions pertaining to geographical scale are not particularly relevant. Thus, such categorizations of optical networks for WAN, MAN, LAN, DAN, SAN, HAN, PAN, long-haul, metro, premise, campus, core, backbone, edge, access, distribution scales are mere "surface" conceptual structures in the Chomskian sense for this purpose.

3. The really "deep" structure is the acceptance that different parts of most transport and forwarding (T&F) infrastructures will be under the control of different "administrative domains" (ADs), which would nevertheless still need to inter-operate to support end-to-end applications and services for distributed communications, messaging, computing, remote and tele-operations, and content, media/multi-media access. However, this need to accommodate ADs is already built into the ConSION model and architecture, right from the beginning.

6.1 Basic Transport & Forwarding (_Switching_) Types

The detailed specifications of what constitute the SOCAR aspects and roles for transport and forwarding are for future documents and beyond the scope of this report. However, it would seem that despite the stupendous diversity of plausible T&F equipment, one could classify the various ways of transport and forwarding according to a small number of basic types of extant technologies for transmission, multiplexing, relay and switching. Thus, for the further development of the ConSION oriented protocol suites, one can identify parts of the T&F overlay network that deal the following basic types of relay modes or "switching", considering the current state of the art.

a. IPv4 forwarding (IP packet switching type 1)
b. IPv6 forwarding (IP packet switching type 2)
c. MPLS forwarding (Label switching or tag switching)
d. ATM Virtual Path (VP) transport (digital switching type 1)
e. ATM Virtual Circuit or FR Virtual Circuit (VC) T&F (type 2)
f. SONET transport (TDM forwarding type 1)

g. SDH transport (TDM forwarding type 2)
h. PDH transport (T1, E1, T3, E3, ISDN, etc.) (TDM T&F type 3)
i. DTR transport (TDM forwarding type 4)
j. WDM (DWDM, CWDM) wavelength switching, incl. conversion

k. WDM waveband switching (type 2)
l. WDM sub-wavelength switching (type 3)
m. WDM fiber strand switching (type 4)
n. WDM fiber (multi-strand) switching (type 5)
o. WDM fiber bundle or cable (multi-fiber) switching (type 6)
p. OFDM switching (type 7)
q. Photonic packet switching (IP packet switching type 3)
r. Other forwarding, transport and switching types.

One can think of the overall T&F overlay network as a multi-colored network made up of a collection of multiple overlay sub-networks. Each overlay sub-network using a particular basic switching (or forwarding and transport) type is given a separate color. So according to the above classification, a comprehensive I.O.N T&F overlay network is likely to be at least an 18-color sub-overlay network.

Each of the above basic forwarding, transport and switching types will need specific open interfaces that define how to explicitly control and manage a _pure_ sub-overlay network built using just the basic type. Thus, there are corresponding colored sub-overlay sub-networks composing the C&S and M&A overlay networks.

The work to define the detailed open interfaces and supporting protocol suites is not as overwhelming as a comprehensive enumeration of the basic T&F (switching) types would suggest. It is clear that the C&S and M&A of the several cases share many similar features. Therefore, one can rely on concepts that the software object orientation community has labeled reuse, inheritance and polymorphism in protocol specifications.

The application the reuse principle in protocol specifications is quite pervasive in the IETF community. However, it has never been systematically elevated to an engineering principle, and systematically applied and supported by automation tools for the (visual) assembly of protocol specifications and definitions.

Furthermore, other concepts from distributed components and object orientation are not only useful for organizing protocol software but also for protocol specifications. Namely,

a. DISTRIBUTED (protocol entities): with attendant focus on inter-operation; operation on different and multiple platforms; collaboration and cooperation of component; and co-existence via translation, adaptation, wrapping and encapsulation.

b. REUSE (of protocol definitions, specifications, details and attribute frames): mainly via translation, adaptation, encapsulation, augmentation, extension and supplementation.

c. INHERITANCE (of protocol abstractions, prototypes, classes,
   instances, components' properties, attributes, relationships

and inter-dependencies): focusing on sub-classes, abstraction, customization and _personalization_.

d. POLYMORPHISM (of manipulations of protocol and interface representations): focusing on functionals, operators and combinators, parameterization.

e. IDL and CRL: Interface Definition Languages and (protocol) Component Representation Languages.

f. META-DATA: introspection, self-describing, self-managing protocol entities.

Thinking in this direction also points to the future of protocol engineering as involving extensive automated protocol development.

6.2 Hybrid Transport & Forwarding Types

There are also hybrid "switching" types formed by inter-working pairs of the basic types, such as those listed above:

```
      a:b, a:c, a:d,..., a:q, a:r _
      p:a, p:b, p:c,..., p:o, p:q, p:r
```

For example, the designation (a:k) means that a particular transport and forwarding scenario starts as IPv4 packet forwarding which then gets inter-worked (mapped) into DWDM wavelength routing via translation, adaptation, wrapping, "tunneling", etc., or vice versa.

The hybrid switching types do not result in an increase in the open interfaces required. The control and management of a hybrid relay type can be achieved by controlling and managing the underlying basic types as well as the inter-working scheme mediating that particular combination.

6.3 Metaphor of a Distinct Central Nervous System

The discussion above on the control and management of basic switching types (as the essential elements of the transport and forwarding overlay networks) indicates that the current debate in the industry and protocol engineering and architecture community concerning "overlay" vs. "peer" approaches to controlling optical networks is in fact a red herring. One short summary of the debate is whether the control "intelligence" should reside in the optical/photonic layer or at the IP/data/electronic layer or both [IPOVON].

The physical SOCAR based ConSION proposal indicates that this is a false distinction. The T&F aspects and overlay networks for next generation networks are likely to involve both Optical elements and IP-based networking elements. Faster progress will be made if the controlling and management intelligences are implemented as physically separate overlay networks. In each case, each overlay network will also include both optical/photonic and electronic/IP network elements. Therefore, the "intelligence" does not really reside in the optical nor in the electronic layer.

According to the CoSION programme, each optical network in the future will have its own distinct and physically separate digital "central nervous system" that controls and manages it, complete with central pattern generators (CPGs) and C&S plus M&A transaction coordinators.

7 The Overlay Networks and Logical SOCAR

A detailed discussion of the aspects and roles that fall into each SOCAR plane are for future documents. Nonetheless, ongoing work in the IETF and other bodies indicates the general outline of how the concerns, aspects and roles are likely to be logically separated and eventually also physically separated.

7.1 Control & Signaling Overlay Network

For the C&S overlay network, the aspects and concerns are likely to include:

a. Automated Provisioning of bandwidth and mapping of traffic flows onto bandwidth channels.

b. Restoration (based on pre-engineered protection schemes and architectures), as well as other Fault Tolerance concerns.

c. Traffic Engineering. The satisficing and optimal use of T&F resources, subject to service constraints and requirements.

d. IP (best-effort) route calculations and IP routing table management.

e. LSP path calculations and LIB management for G/MPLS.

7.2 Management & Administration Overlay Network

The aspects to be implemented in this overlay network are likely to include:

a. Operations support and OSS inter-working.

b. Network management, using schemes such as TNM (Total Network Management), GSMP [GSMPx01], SNMP and MIB management.

c. The various types of "engineering management", including performance management, availability management, security management, accounting management (metering, measurements, mediation, etc.)

d. Facilities management, assets and inventory management.

e. Management inter-working.

f. Life cycle support (LCS) aspects and concerns, including Installation, Testing and Cutover (ITC); Operational Control Administration (OCA); Operations Administration and Management (OAM); Maintenance and Repair Operations (MRO); and Upgrades, Transitions and (tech) Migrations (UTM).

g. Various analytics in support of network management, concerned involving networking oriented data warehousing and data mining.

7.3 Service Engineering Overlay Network

The aspects and concerns to be implemented in this overlay network are likely to include:

a. Service provisioning for various classes of flows. These classes will include differentiated, integrated and convergent services and media, as well as traditional voice, data and video.

b. Issues of billing, billing mediation and inter-AD billing presentment.

c. Customer care and support (CCS) and customer relationship management (CRM)

d. Service-oriented business development and inter-working

e. Customer or user education, training and learning (ETL), regarding I.O.N.

8 Security Considerations

Security management will be implemented primarily in the Management & Administration Overlay Network. Furthermore, for each overlay network, whenever flows and interactions cross AD boundaries, security issues of identification, authentication, authorization, delegation and gate-keeping functions will become very important. ConSION based protocol suites will need to make ample provisions for security and security fault tolerance.

9 Summary and Conclusions

This memo proposes that the physical SOCAR (separation of concerns, aspects and roles) principle be explicitly applied to the future development of protocols for optical networking (including UNI, NNI, MPLS, GMPLS, "optical" MPLS, etc.) This will be in line with the emergence of the physical overlay network approach to the operational deployment of optical networking infrastructures and a significant role for "softswitch"-like control & signaling engines and servers.

The start of the CoSION approach to protocol development will merely require the careful separation of the aspects transport & forwarding, control & signaling, management & administration, and service creation & engineering, which are all intermixed and conflated in the existing protocols from the IETF, ODSI, OIF and ITU (for example, for G/MPLS, UNIs and NNIs). Afterwards, the protocol suites for the various overlay networks can proceed semi-autonomously, except for their inter-dependent touch points.

The ConSION proposal is advocating that the ideas involved in logical SOCAR be taken to the ultimate conclusion by explicitly formulating next generation network control and management protocol suites to also support physical SOCAR. The current trend in the industry shows that such physical separation is inevitable in the near future, so it can be acknowledged, accommodated and used systematically to drive all further relevant protocol suite development in a body such as the IETF.

Once the principle of physical separation and embodiment is accepted, the proposal is also advocating that open interfaces should be defined within and between the overlay networks, so as to allow multiple vendors to focus on their core competencies and strengths so that monolithic solutions and products (both hardware and software) are no longer what drive the industry.

The outlines of the general ideas of what aspects and roles belong to which overlay network have also been identified. Further work is needed to re-package existing protocol suites so that they allow the application of the physical SOCAR principle.

With the ConSION approach each future optical networking infrastructure will have its own distinct "central nervous system" to coordinate, control and manage it. Furthermore the CNS of the various networks will be readily and collectively inter-worked to form network societies or a distributed, cooperatively intelligent super-organism.

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