Interworking of GMPLS Control and Centralized Controller System

draft-zheng-teas-gmpls-controller-inter-work-03

Abstract

   Generalized Multi-Protocol Label Switching (GMPLS) control allows
   each network element (NE) to perform local resource discovery,
   routing and signaling in a distributed manner.

   On the other hand, with the development of software-defined
   transport networking technology, a set of NEs can be controlled via
   centralized controller hierarchies to address the issue from multi-
   domain, multi-vendor and multi-technology. An example of such
   centralized architecture is ACTN controller hierarchy described in
   RFC 8453.

   Instead of competing with each other, both the distributed and the
   centralized control plane have their own advantages, and should be
   complementary in the system. This document describes how the GMPLS
   distributed control plane can interwork with a centralized
   controller system in a transport network.

Status of this Memo

at any time. It is inappropriate to use Internet-Drafts as
reference material or to cite them other than as "work in progress."

The list of current Internet-Drafts can be accessed at
http://www.ietf.org/ietf/1id-abstracts.txt.

The list of Internet-Draft Shadow Directories can be accessed at
http://www.ietf.org/shadow.html.

This Internet-Draft will expire on August 19, 2019.

Copyright Notice

Conventions used in this document

Table of Contents

1. Introduction

   Generalized Multi-Protocol Label Switching (GMPLS) [RFC3945] extends
   MPLS to support different classes of interfaces and switching
   capabilities such as Time-Division Multiplex Capable (TDM), Lambda
   Switch Capable (LSC), and Fiber-Switch Capable (FSC). Each network
   element (NE) running a GMPLS control plane collects network
   information from other NEs and supports service provisioning through
   signaling in a distributed manner. More generic description for
   Traffic-engineering networking information exchange can be found in
   [RFC7926].

   On the other hand, Software-Defined Networking (SDN) technologies
   have been introduced to control the transport network in a
   centralized manner. Central controllers can collect network
   information from each node and provision services to corresponding
   nodes. One of the examples is the Abstraction and Control of Traffic
   Engineered Networks (ACTN) [RFC8453], which defines a hierarchical
   architecture with Provisioning Network Controller(PNC), Multi-domain
   Service Coordinator(MDSC) and Customer Network Controller(CNC) as
   central controllers for different network abstraction levels. A Path
   Computation Element (PCE) based approach has been proposed as
   Application-Based Network Operations (ABNO) in [RFC7491].

   In such centralized controller architectures, GMPLS can be applied
   for the NE-level control. A central controller may support GMPLS
   enabled domains and may interact with a GMPLS enabled domain where
   the GMPLS control plane does the service provisioning from ingress
   to egress. In this case the centralized controller sends the request
   to the ingress node and does not have to configure all NEs along the
   path through the domain from ingress to egress thus leveraging the
   GMPLS control plane. This document describes how GMPLS control
   interworks with centralized controller system in transport network.

[2](#). Overview

In this section, overviews of GMPLS control plane and centralized
controller system are discussed as well as the interactions between
the GMPLS control plane and centralized controllers.

[2.1](#). Overview of GMPLS Control Plane

GMPLS separates the control plane and the data plane to support
time-division, wavelength, and spatial switching, which are
significant in transport networks. For the NE level control in
GMPLS, each node runs a GMPLS control plane instance.
Functionalities such as service provisioning, protection, and
restoration can be performed via GMPLS communication among multiple
NEs. At the same time, the controller can also collect node and
link resources in the network to construct the network topology and
compute routing paths for serving service requests.

Several protocols have been designed for GMPLS control [[RFC3945](#)]
including link management [[RFC4204](#)], signaling [[RFC3471](#)], and
routing [[RFC4202](#)] protocols. The controllers applying these
protocols communicate with each other to exchange resource
information and establish Label Switched Paths (LSPs). In this way,
controllers in different nodes in the network have the same view of
the network topology and provision services based on local policies.

[2.2](#). Overview of Centralized Controller System

With the development of SDN technologies, a centralized controller
architecture has been introduced to transport networks. One example
architecture can be found in ACTN [[RFC8453](#)]. In such systems, a
controller is aware of the network topology and is responsible for
provisioning incoming service requests.

Multiple hierarchies of controllers are designed at different levels
implementing different functions. This kind of architecture enables
multi-vendor, multi-domain, and multi-technology control. For
example, an higher-level controller coordinates several lower-level
controllers controlling different domains, for topology collection
and service provisioning. Vendor-specific features can be abstracted
between controllers, and standard API (e.g., generated from
RESTconf/YANG) is used.

[2.3](#). GMPLS Control Interwork with Centralized Controller System

Besides the GMPLS and the interactions among the controller
hierarchies, it is also necessary for the controllers to communicate
with the network elements. Within each domain, GMPLS control can be
applied to each NE. The bottom-level central controller can act as a

NE to collect network information and initiate LSP. Figure 1 shows

an example of GMPLS interworking with centralized controllers (ACTN
terminologies are used in the figure).

```
                    +----------+
                    |   MDSC   |
                    +----------+
                      ^       ^
                      |       |
              +---------+   +---------+
              |   RESTConf / YANG models  |
                 V                        V
           +---------+            +---------+
           |   PNC   |            |   PNC   |
           +---------+            +---------+
             ^   ^                  ^   ^
             |   |                  |   |
        Netconf|   |PCEP       Netconf|   |PCEP
         /YANG |   |           /YANG |   |
             V   V                  V   V
         .-------------.   Inter-   .-------------.
        /               \ domain  /               \
       |     LMP          | link  |     LMP         |
       |     OSPF-TE    ========= |     OSPF-TE     |
       |     RSVP-TE      |       |     RSVP-TE     |
        \               /          \               /
         `------------`             `------------`
           GMPLS domain              GMPLS domain
```
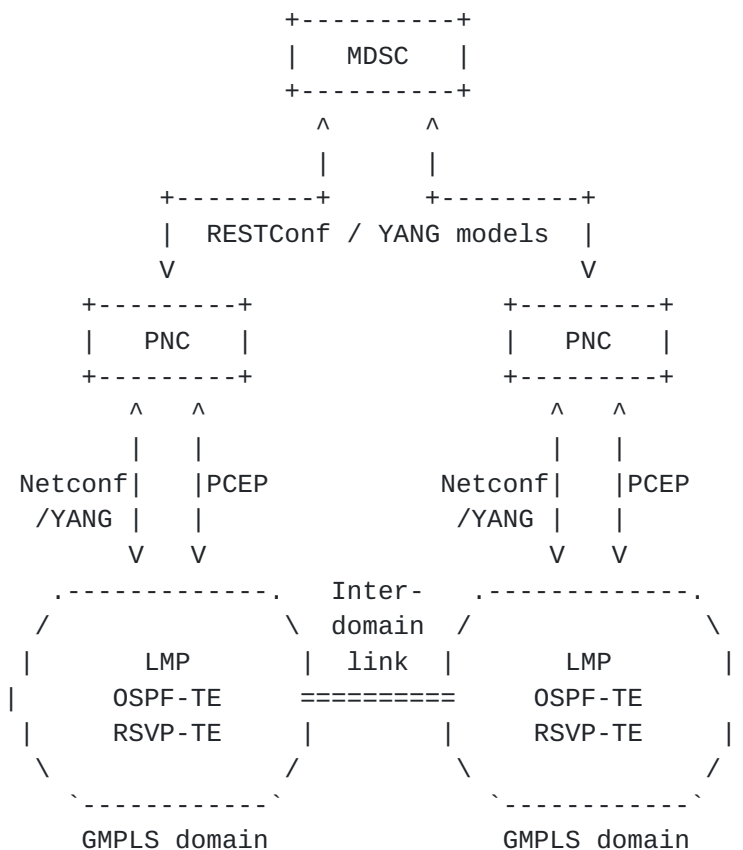
Figure 1: Example of GMPLS interworks with Controllers

In Figure 1, each domain has the GMPLS control plane enabled at the
physical network level. The PNC can exploit GMPLS capability
implemented in the domain to listen to the IGP routing protocol
messages (OSPF LSAs for example) that the GMPLS control plane
instances are disseminating into the network and thus learn the
network topology. For path computation in the domain with PNC
implementing a PCE, PCCs (e.g. NEs, other controller/PCE) use PCEP
to ask the PNC for a path and get replies. The MDSC communicates
with PNCs using for example REST/RESTConf based on YANG data models.
As a PNC has learned its domain topology, it can report the topology
to the MDSC. When a service arrives, the MDSC computes the path and
coordinates PNCs to establish the corresponding LSP segment.

Alternatively, the NETCONF protocol can be used to retrieve topology
information utilizing the e.g.[TE-topo] Yang model and the
technology-specific YANG model augmentations required for the

specific network technology. The PNC can retrieve topology
information from any NE (the GMPLS control plane instance of each NE
in the domain has the same topological view), construct the topology
of the domain and export an abstracted view to the MDSC. Based on
the topology retrieved from multiple PNCs, the MDSC can create
topology graph of the multi-domain network, and can use it for path
computation. To setup a service, the MDSC can exploit e.g.[TE-
Tunnel] Yang model together with the technology-specific YANG model
augmentations.

3. Link Management Protocol

Link management protocol (LMP) [RFC4204] runs between a pair of
nodes and is used to manage TE links. In addition to the setup and
maintenance of control channels, LMP can be used to verify the data
link connectivity and correlate the link property. In this way, link
resources, which are fundamental resources in the network, are
discovered by both ends of the link.

4. Routing Options

In GMPLS control, link state information is flooded within the
network as defined in [RFC4202]. Each node in the network can build
the network topology according to the flooded link state
information. Routing protocols such as OSPF-TE [RFC4203] and ISIS-TE
[RFC5307] have been extended to support different interfaces in
GMPLS.

In centralized controller system, central controller can be placed
at the GMPLS network and passively receive the information flooded
in the network. In this way, the central controller can construct
and update the network topology.

4.1. OSPF-TE

OSPF-TE is introduced for TE networks in [RFC3630]. OSPF extensions
have been defined in [RFC4203] to enable the capability of link
state information for GMPLS network. Based on this work, OSPF
protocol has been extended to support technology-specific routing.
The routing protocol for OTN, WSON and optical flexi-grid network
are defined in [RFC7138], [RFC7688] and [RFC8363], respectively.

4.2. ISIS-TE

ISIS-TE is introduced for TE networks in [RFC5305] and is extended
to support GMPLS routing functions [RFC5307], and has been updated
to [RFC7074] to support the latest GMPLS switching capability and
Types fields.

4.3. Netconf/RESTconf

Netconf [RFC6241] and RESTconf [RFC8040] protocols are originally
used for network configuration. Besides, these protocols can also be
used for topology retrieval by using topology-related YANG models,
such as [RFC8345] and [TE-topo]. These protocols provide a powerful
mechanism for notification that permits to notify the client about
topology changes.

5. Path Computation

Once a controller learns the network topology, it can utilize the
available resources to serve service requests by performing path
computation. Due to abstraction, the controllers may not have
sufficient information to compute the optimal path. In this case,
the controller can interact with other controllers by sending Yang
Path Computation requests [PAT-COMP] to compute a set of potential
optimal paths and then, based on its own constraints, policy and
specific knowledge (e.g. cost of access link) can choose the more
feasible path for service e2e path setup.

Path computation is one of the key objectives in various types of
controllers. In the given architecture, it is possible for different
components that have the capability to compute the path.

5.1. Constraint-based Path Computing in GMPLS Control

In GMPLS control, a routing path is computed by the ingress node
[RFC3473] and is based on the ingress node TED. Constraint-based
path computation is performed according to the local policy of the
ingress node.

5.2. Path Computation Element (PCE)

PCE has been introduced in [RFC4655] as a functional component that
provides services to compute path in a network. In [RFC5440], the
path computation is accomplished by using the Traffic Engineering
Database (TED), which maintains the link resources in the network.
The emergence of PCE efficiently improve the quality of network
planning and offline computation, but there is a risk that the
computed path may be infeasible if there is a diversity requirement,
because stateless PCE has no knowledge about the former computed
paths.

To address this issue, stateful PCE has been proposed in [RFC8231].
Besides the TED, an additional LSP Database (LSP-DB) is introduced
to archive each LSP computed by the PCE. In this way, PCE can easily
figure out the relationship between the computing path and former
computed paths. In this approach, PCE provides computed paths to

PCC, and then PCC decides which path is deployed and when to be established.

In PCE Initiation [RFC8281], PCE is allowed to trigger the PCC to setup, maintenance, and teardown of the PCE-initiated LSP under the stateful PCE model. This would allow a dynamic network that is centrally controlled and deployed.

In centralized controller system, the PCE can be implemented in a central controller, and the central controller performs path computation according to its local policies. On the other hand, the PCE can also be placed outside of the central controller. In this case, the central controller acts as a PCC to request path computation to the PCE through PCEP. One of the reference architecture can be found at [RFC7491].

6. Signaling Options

Signaling mechanisms are used to setup LSPs in GMPLS control. Messages are sent hop by hop between the ingress node and the egress node of the LSP to allocate labels. Once the labels are allocated along the path, the LSP setup is accomplished. Signaling protocols such as RSVP-TE [RFC3473] have been extended to support different interfaces in GMPLS.

6.1. RSVP-TE

RSVP-TE is introduced in [RFC3209] and extended to support GMPLS signaling in [RFC3473]. Several label formats are defined for a generalized label request, a generalized label, suggested label and label sets. Based on [RFC3473], RSVP-TE has been extended to support technology-specific signaling. The RSVP-TE extensions for OTN, WSON, optical flexi-grid network are defined in [RFC7139], [RFC7689], and [RFC7792], respectively.

7. Interworking Scenarios

7.1. Topology Collection & Synchronization

Topology information is necessary on both network elements and controllers. The topology on network element is usually raw information, while the topology on the controller can be either raw or abstracted. Three different abstraction methods have been described in [RFC8453], and different controllers can select the corresponding method depending on application.

When there are changes in the network topology, the impacted network element(s) need to report changes to all the other network elements, together with the controller, to sync up the topology information.

The inter-NE synchronization can be achieved via protocols mentioned

in [section 3](#) and 4. The topology synchronization between NEs and
controllers can either be achieved by routing protocols OSPF-
TE/PCEP-LS in [PCEP-LS] or Netconf protocol notifications with YANG
model.

7.2. Multi-domain/layer Service Provisioning

Based on the topology information on controllers and network
elements, service provisioning can be deployed. Plenty of methods
have been specified for single domain service provisioning, such as
using PCEP and RSVP-TE.

Multi-domain/layer service provisioning would request coordination
among the controller hierarchies. Given the service request, the
end-to-end delivery procedure may include interactions at any level
(i.e. interface) in the hierachy of the controllers (e.g. MPI and
SBI for ACTN). The computation for a cross-domain/layer path is
usually completed by controllers who have a global view of the
topologies. Then the configuration is decomposed into lower layer
controllers, to configure the network elements to set up the path.

A combination of the centralized and distributed protocols may be
necessary for the interaction between network elements and
controller. A typical example would be the PCE Initiation scenario,
in which a PCE message (PCInitiate) is sent from the controller to
the first-end node, and then trigger a RSVP procedure along the
path. Similarly, the interaction between the controller and the
ingress node of a domain can be achieved by Netconf protocol with
corresponding YANG models, and then completed by running RSVP among
the network elements.

7.3. Recovery

The GMPLS recovery functions are described in [RFC4426]. Two models,
span protection and end-to-end protection and restoration, are
discussed with different protection schemes and message exchange
requirements. Related RSVP-TE extensions to support end-to-end
recovery is described in [RFC4872]. The extensions in [RFC4872]
include protection, restoration, preemption, and rerouting
mechanisms for an end-to-end LSP. Besides end-to-end recovery, a
GMPLS segment recovery mechanism is defined in [RFC4873]. By
introducing secondary record route objects, LSP segment can be
switched to another path like fast reroute [RFC4090].

For the recovery with controllers, timely interaction between
controller and network elements are required. Usually the re-routing
can be decomposed into path computation and delivery, the controller
can take some advantage in the path computation due to the global

topology view. And the delivery can be achieved by the procedure
described in [section 7.2](#).

7.4. Controller Reliability

Given the important role in the network, the reliability of
controller is critical. Once a controller is shut down, the network
should operate as well. It can be either achieved by controller back
up or functionality back up. There are several of controller backup
or federation mechanisms in the literature. It is also more reliable
to have some function back up in the network element, to guarantee
the performance in the network.

8. Manageability Considerations

Each entity in the network, including both controllers and network
elements, should be managed properly as it will interact with other
entities. The manageability considerations in controller hierarchies
and network elements still apply respectively. For the protocols
applied in the network, manageability is also requested.

The responsibility of each entity should be clarified. The control
of function and policy among different controllers should be
consistent via proper negotiation process.

9. Security Considerations

This document provides the interwork between the GMPLS and
controller hierarchies. The security requirements in both system
still applies respectively. Protocols referenced in this document
also have various security considerations, which is also expected to
be satisfied.

Other considerations on the interface between the controller and the
network element are also important. Such security includes the
functions to authenticate and authorize the control access to the
controller from multiple network elements. Security mechanisms on
the controller are also required to safeguard the underlying network
elements against attacks on the control plane and/or unauthorized
usage of data transport resources.

10. IANA Considerations

This document requires no IANA actions.

11. References

11.1. Normative References

[RFC3209] Awduche, D., Berger, L., Gan, D., Li, T., Srinivasan, V.,
           and G. Swallow, "RSVP-TE: Extensions to RSVP for LSP
           Tunnels", RFC 3209, December 2001.

   [RFC3473] Berger, L., Ed., "Generalized Multi-Protocol Label
              Switching (GMPLS) Signaling Resource ReserVation Protocol-
              Traffic Engineering (RSVP-TE) Extensions", RFC 3473,
              January 2003.

   [RFC3630] Katz, D., Kompella, K., and D. Yeung, "Traffic
              Engineering (TE) Extensions to OSPF Version 2", RFC 3630,
              September 2003.

   [RFC3945] Mannie, E., Ed., "Generalized Multi-Protocol Label
              Switching (GMPLS) Architecture", RFC 3945, October 2004.

   [RFC4203] Kompella, K., Ed. and Y. Rekhter, Ed., "OSPF Extensions
              in Support of Generalized Multi-Protocol Label Switching
              (GMPLS)", RFC 4203, October 2005.

   [RFC4655] Farrel, A., Vasseur, J., and J. Ash, "A Path Computation
              Element (PCE)-Based Architecture", RFC 4655, August 2006.

   [RFC4872] Lang, J., Ed., Rekhter, Y., Ed., and D. Papadimitriou,
              Ed., "RSVP-TE Extensions in Support of End-to-End
              Generalized Multi-Protocol Label Switching (GMPLS)
              Recovery", RFC 4872, May 2007.

   [RFC4873] Berger, L., Bryskin, I., Papadimitriou, D., and A.
              Farrel, "GMPLS Segment Recovery", RFC 4873, May 2007.

   [RFC5305] Li, T. and H. Smit, "IS-IS Extensions for Traffic
              Engineering", RFC 5305, October 2008.

   [RFC5307] Kompella, K., Ed. and Y. Rekhter, Ed., "IS-IS Extensions
              in Support of Generalized Multi-Protocol Label Switching
              (GMPLS)", RFC 5307, October 2008.

   [RFC5440] Vasseur, JP., Ed. and JL. Le Roux, Ed., "Path Computation
              Element (PCE) Communication Protocol (PCEP)", RFC 5440,
              March 2009.

   [RFC6241] Enns, R., Bjorklund, M., Schoenwaelder J., Bierman A.,
              "Network Configuration Protocol (NETCONF)", RFC 6241, June
              2011.

   [RFC7074] Berger, L. and J. Meuric, "Revised Definition of the
              GMPLS Switching Capability and Type Fields", RFC 7074,
              November 2013.

   [RFC7491] King, D., Farrel, A., "A PCE-Based Architecture for
             Application-Based Network Operations", RFC7491, March
             2015.

   [RFC7926] Farrel, A., Drake, J., Bitar, N., Swallow, G., Ceccarelli,
             D. and Zhang, X., "Problem Statement and Architecture for
             Information Exchange between Interconnected Traffic-
             Engineered Networks", RFC7926, July 2016.

   [RFC8040] Bierman, A., Bjorklund, M., Watsen, K., "RESTCONF
             Protocol", RFC 8040, January 2017.

   [RFC8453] Ceccarelli, D. and Y. Lee, "Framework for Abstraction and
             Control of Traffic Engineered Networks", RFC 8453, August
             2018.

11.2. Informative References

   [RFC3471] Berger, L., Ed., "Generalized Multi-Protocol Label
             Switching (GMPLS) Signaling Functional Description", RFC
             3471, January 2003.

   [RFC4090] Pan, P., Ed., Swallow, G., Ed., and A. Atlas, Ed., "Fast
             Reroute Extensions to RSVP-TE for LSP Tunnels", RFC 4090,
             May 2005.

   [RFC4202] Kompella, K., Ed. and Y. Rekhter, Ed., "Routing Extensions
             in Support of Generalized Multi-Protocol Label Switching
             (GMPLS)", RFC 4202, October 2005.

   [RFC4204] Lang, J., Ed., "Link Management Protocol (LMP)", RFC
             4204, October 2005.

   [RFC4426] Lang, J., Ed., Rajagopalan, B., Ed., and D.
             Papadimitriou, Ed., "Generalized Multi-Protocol Label
             witching (GMPLS) Recovery Functional Specification", RFC
             4426, March 2006.

   [RFC7138] Ceccarelli, D., Ed., Zhang, F., Belotti, S., Rao, R., and
             J. Drake, "Traffic Engineering Extensions to OSPF for
             GMPLS Control of Evolving G.709 Optical Transport
             Networks", RFC 7138, March 2014.

   [RFC7139] Zhang, F., Ed., Zhang, G., Belotti, S., Ceccarelli, D.,
             and K. Pithewan, "GMPLS Signaling Extensions for Control
             of Evolving G.709 Optical Transport Networks", RFC 7139,
             March 2014.

   [RFC7688] Lee, Y., Ed. and G. Bernstein, Ed., "GMPLS OSPF
             Enhancement for Signal and Network Element Compatibility
             for Wavelength Switched Optical Networks", RFC 7688,
             November 2015.

   [RFC7689] Bernstein, G., Ed., Xu, S., Lee, Y., Ed., Martinelli, G.,
             and H. Harai, "Signaling Extensions for Wavelength
             Switched Optical Networks", RFC 7689, November 2015.

   [RFC7792] Zhang, F., Zhang, X., Farrel, A., Gonzalez de Dios, O.,
             and D. Ceccarelli, "RSVP-TE Signaling Extensions in
             Support of Flexi-Grid Dense Wavelength Division
             Multiplexing (DWDM) Networks", RFC 7792, March 2016.

   [RFC8231] Crabbe, E., Minei, I., Medved, J., and R. Varga, "Path
             Computation Element Communication Protocol (PCEP)
             Extensions for Stateful PCE", RFC 8231, September 2017.

   [RFC8281] Crabbe, E., Minei, I., Sivabalan, S., and R. Varga, "PCEP
             Extensions for PCE-initiated LSP Setup in a Stateful PCE
             Model", RFC 8281, October 2017.

   [RFC8345] Clemm, A., Medved, J., Varga, R., Bahadur, N.,
             Ananthakrishnan, H., Liu, X., "A YANG Data Model for
             Network Topologies", RFC 8345, March 2018.

   [RFC8363] Zhang, X., Zheng, H., Casellas, R., Dios, O., and D.
             Ceccarelli, "GMPLS OSPF-TE Extensions in support of Flexi-
             grid DWDM networks", RFC8363, February 2017.

   [TE-topo] Liu, X., Bryskin, I., Beeram, V., Saad, T., Shah, H.,
             Gonzalez De Dios, O., "YANG Data Model for Traffic
             Engineering (TE) Topologies", draft-ietf-teas-yang-te-
             topo-19, work in progress.

   [PAT-COMP] Busi, I., Belotti, S., Lopez, V., Gonzalez de Dios, O.,
             Sharma, A., Shi, Y., Vilalta, R., Setheraman, K., "Yang
             model for requesting Path Computation", draft-ietf-teas-
             yang-path-computation-04, work in progress.

   [PCEP-LS] Dhody, D., Lee, Y., Ceccarelli, D., "PCEP Extensions for
             Distribution of Link-State and TE Information", draft-
             dhodylee-pce-pcep-ls, work in progress.

   [TE-Tunnel] Saad, T. et al., "A YANG Data Model for Traffic
             Engineering Tunnels and Interfaces", draft-ietf-teas-yang-
             te, work in progress.

[12](). Authors' Addresses

Haomian Zheng
Huawei Technologies
F3 R&D Center, Huawei Industrial Base,
Bantian, Longgang District,
Shenzhen 518129 P.R.China
Email: zhenghaomian@huawei.com

Xianlong Luo
Huawei Technologies
F3 R&D Center, Huawei Industrial Base,
Bantian, Longgang District,
Shenzhen 518129 P.R.China
Email: luoxianlong@huawei.com

Yunbin Xu
CAICT
Email: xuyunbin@ritt.cn

Yang Zhao
China Mobile
 Email: zhaoyangyjy@chinamobile.com

Sergio Belotti
Nokia
Email: sergio.belotti@nokia.com

Dieter Beller
Nokia
Email: Dieter.Beller@nokia.com