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Problem Statements of Scalable Synchronization Networks
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Abstract

With the wide deployment of 4G and beyond mobile networks, a great number of cells need high precision frequency and/or time synchronization for their normal operation. It is crucial to manage the synchronization network in a scalable way and simplify the monitoring and operation for synchronization networks. This document analyzes the use cases and requirements in synchronization networks, and provides a problem statement for scalable synchronization networks.

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1. Introduction

In modern communication networks, most telecommunication services require that the frequency or phase difference between the whole network equipments should be kept within the reasonable range. Especially for mobile networks, there is a requirement for high precision network clock synchronization, including frequency synchronization and phase synchronization.

For packet switching networks, SyncE and IEEE 1588v2 protocols are widely deployed for frequency and time synchronization respectively in mobile network. Synchronization path planning and provisioning are very complex as so many parameters (e.g., quality level, priority,

synchronization enable/disable, hop limit, holdover timeout, and etc) need to be configured. Furthermore, configuration of SyncE must not introduce any loops in the synchronization paths. Hence, deployment of synchronization network requires professional skills in synchronization protocols and also the engineering capability in analyzing and planning the network topology.

With the deployment of 4G network, the density of cells is explosively growing, as a result, the size of mobile networks and its backhaul network has greatly increased (it may consist of tens of thousands of network equipments in a single metro city). This scalability requirement will pose a great challenge to realize synchronization, and the management and monitoring of the synchronization network becomes dramatically more complex for service providers.

In the past, management and monitoring of synchronization networks are mainly resorted to manual configuration and manual diagnosis, which are complex, error-prone and very time-consuming. Thus it is hard to avoid synchronization loops, erroneous configuration and other mistakes. Therefore, it is important to provide some tools to improve the efficiency of fault monitoring and detection in synchronization networks.

As the synchronization is critical for the mobile services, it will beneficial to provide path protection for synchronization networks, so that single point of synchronization failure can be avoided (or even provide multipoint protection as much as possible, i.e., even when the working path and a protection synchronization path are both lost, the network can figure out a new synchronization path so that frequency source is still available. This may require that a third synchronization port be configured as a recovery port).

Furthermore, as the mobile network size increases dramatically, the synchronization performance is hard to be satisfied, e.g., care must be taken to guarantee that a certain hop limit (e.g. 20 hops) of time-distribution from the timing source to a cell site is not exceeded.

This document provides some use cases and requirements on configuration and management of a large synchronization network and provides problem statements for scalable synchronization networks.

1.1. Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

1.2. Terminology

OAM: Operation Administration and Maintenance

BMCA: best master clock algorithm

T-GM: Telecom Grandmaster, a device consisting of a Boundary Clock as defined in [IEEE-1588], with additional performance characteristics defined in [G.8273.2].

2. Use cases for scalable synchronization network

Following are some use cases of scalable synchronization networks from a management and operation viewpoint.

2.1. Synchronization configuration

In a huge mobile backhaul network with more than 10,000 nodes, manual planning and provisioning of synchronization network are very onerous. For example, manual planning and configuration for a simple network may need more than several weeks; furthermore, it is error-prone. And the planning can't eliminate the risk of introducing loops to a synchronization network.

To facilitate synchronization configuration, a central controller may be introduced. The controller shall automatically compute, plan and provision the synchronization paths based on the overall physical network topology, thus it can eliminate the risks associated with manual planning.

A typical controller for synchronization network can compute and provision a synchronization network with tens of thousands of nodes in just a few minutes, and it is guaranteed that no synchronization loop will be introduced if the algorithm is correctly implemented. Synchronization configuration via a centralized controller requires that the controller be highly efficient, agile and reliable.

To accommodate for different types of equipment implementations, a common interface is needed for synchronization network configuration and management, it can further provide the ability to retrieve the network's synchronization configuration and states of a protocol engine in a device. For example, whether the device is locked or not, what is the port state of PTP port (i.e., master, slave or passive), the current port ID associated with a frequency source in syncE, and etc... This capability is essential for the management and maintenance of synchronization networks.

2.2. Synchronization OAM

In the maintenance of a huge synchronization network, an operator may encounter various synchronization problems. The traditional manual trouble shooting hop by hop is very onerous. Even if the malfunction equipments are located in a single operator network, the fault detection procedure is very tedious, let alone in the case of network interworking with a third party.

Traditionally, synchronization fault detection is done by checking synchronization devices on a path one by one manually. I.e., an operator must login to the device (i.e. the device is adjacent to the fault base station or the device nearest to the base station among the devices with the clock alarm), read the configuration information, status and clock alarms information. After analyzing all the information, if the operator still can't locate the source for the fault, the operator must find the upstream device according to the synchronization status information (i.e. the port state of 1588v2 and the current tracing clock port ID of syncE). The operator must login to each upstream device and check the synchronization information one by one, until the source device of the synchronization fault is found.

If the operator cannot locate the fault by the current limited information from the equipments, the operator may have to test the synchronization performance manually by instrument.

This procedure requires that the operator must have a deep understanding of the synchronization protocols and principle of synchronization engineering. And it also is very time-consuming, and sometimes, detecting a single clock fault may even cost up to ten days.

Sometimes the clock synchronization performance of base station degraded but no clock alarm is raised. Through synchronization fault detection an operator cannot locate the true reason of service

disruption. In that case, synchronization performance monitoring may solve the problem by dynamically monitoring the synchronization performance of all devices in the clock synchronization path for a base station in problem.

Therefore, the functions of synchronization OAM shall include synchronization fault detection and synchronization performance monitoring, both are vital in the diagnosis of a synchronization network.

2.3. Synchronization network protection and recovery

If a synchronization path is broken or degraded, it will seriously influence the clock performance of the synchronization network, and further affect the other services of the mobile network. Thus protection and recovery of the synchronization network are very necessary.

In general, if allowed by the network topology, the equipment should be provisioned with a working and a protection synchronization path for SyncE in a mobile network. Thus, the equipments in the mobile network can realize synchronization protection with both the working and backup clock ports.

Even when neither the clock signal on the working port nor on the backup port is available (i.e. loss of signal or degrade of SNR (Signal to Noise Ratio)), the equipment shall not lose the timing source if there is connectivity to it. Ideally, the equipment should select a third port with normal clock signal as a recovery port. And the clock signal of the recovery port mustn't be from the equipment itself (otherwise, a loop will be formed). When the clock signal of the working port or backup port returns to normal, the device may restore to the working or backup port.

In the time synchronization with the IEEE 1588v2, multiple time synchronization ports of the device should be enabled. Through the BMCA automatically selecting the time source can realize the protection and recovery of the time source.

Central controller can also be a solution choice for this use case, for example, provisioning and configuration of the recovery port in advance or dynamic computation and configuration of the recovery port on the fly.

2.4. Multi-layer/Multi-domain synchronization network

In general, to guarantee the time synchronization accuracy, the suggested hop restriction value from the frequency source to the end equipment is 20 in the synchronization network. And the suggested hop restriction value from the time source to the end equipment is 30. The values may be defined differently for different operators.

As tens of thousands of equipments needs to be supported in the same synchronization network, the planning, maintenance and performance of synchronization network face new challenges, for example, the end equipments may hardly satisfy the hop restriction in synchronization. Hierarchical division of a huge synchronization network into multi-layers and/or multi-domains may improve the scalability. For example, the whole synchronization network can be divided into several domains according to their locations.

The operators may also face new challenges after introducing the multi-layer/multi-domain synchronization network, for example, the synchronization OAM for the inter-domain synchronization network is more complex. In the deployment of syncE, the clock fault or performance degradation of edge devices in one domain may even influence the devices of other adjacent domains.

3. Synchronization Requirements

In order to facilitate the provision and management of a large synchronization network, the following requirements need to be addressed:

a) The synchronization network should support a generic, vendor-independent and protocol-neutral information model for synchronization to support heterogeneous networks;

b) The synchronization network should support automatic configuration of frequency and time synchronization parameters based on the generic information model, which may requires a generic configuration interface;

c) The synchronization network should provide high reliability and resiliency, which requires that each synchronization device should maintain at least two useable timing source and switch to an alternate timing source automatically when faults occur in the network; furthermore, a device should restore to the working path when the working path is recovered.

d) The synchronization network should provide high scalability, which may require a network supports to be divided into multiple logical domains defining the scope of synchronization distribution, or require a synchronization protocol to maintain high precision timing signal along a long synchronization path. From the management viewpoint, the network is required to support provision and management by a central controller(even for multi-layer/multi-domain case), or each synchronization device should adjust its timing source automatically when the network adds or removes devices;

e) The synchronization network should provide distributed signaling and centralized signaling to support the traditional network architecture and the innovative SDN architecture;

f) The synchronization network should provide flexible OAM (Operation Administration and Maintenance) functions for synchronization, such as troubleshooting and synchronization performance monitoring, which can be called on demand if the requested timing performance is not met.

4. Security Considerations

It will be considered in a future revision.

5. IANA Considerations

There are no IANA actions required by this document.

6. References

6.1. Normative References

[IEEE-1588]IEEE 1588, Precision Clock Synchronization Protocol for Networked Measurement and Control Systems, 2008

6.2. Informative References

[G.8261] ITU-T, Timing and synchronization aspects in packet networks, August, 2013

[G.8275] ITU-T, Architecture and requirements for packet-based time and phase distribution, November, 2013 [ptp-mib] Shankarkumar, V., Montini, L., Frost, T., and Dowd, G., Precision Time Protocol Version 2 (PTPv2) Management Information Base, draft-ietf-tictoc-ptp-mib-06, work in progress

7. Acknowledgments

TBD

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