**DetNet
Backhaul Networks**

draft-wang-detnet-backhaul-architecture-00
draft-wang-detnet-joint-scheduling-00

Heng Wang, Ping Wang , Lun Shao

wangheng@cqupt.edu.cn, wangping@cqupt.edu.cn, yjssslcqupt@163.com

Chongqing University of Posts and Telecommunications, China

Chicago, March 27, 2017

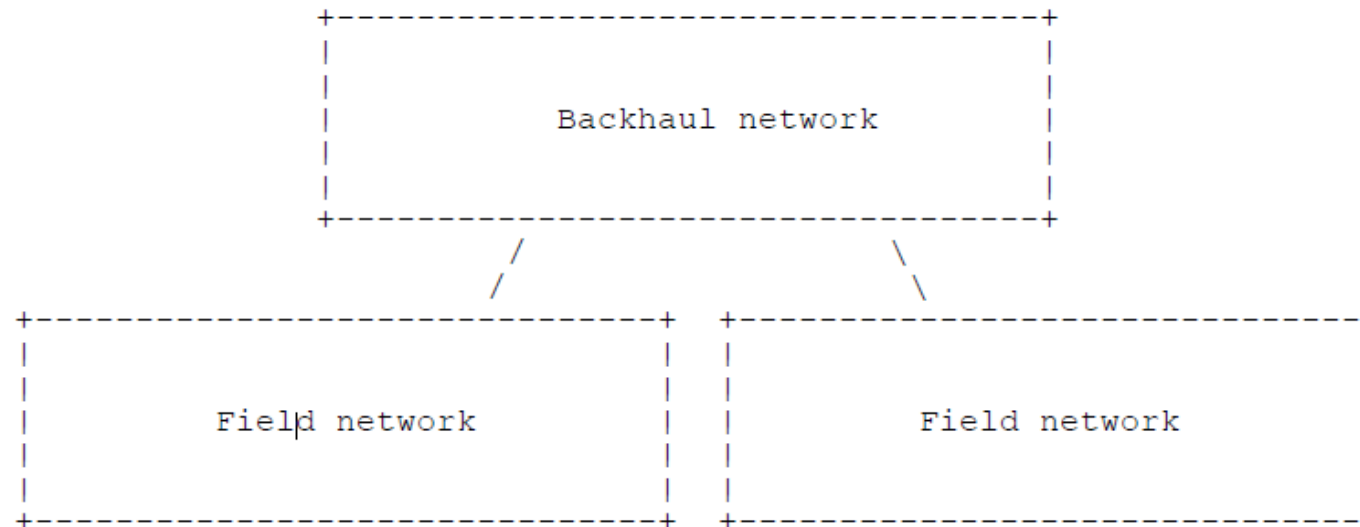# Motivation and Background

- Describes
  - Industrial backhaul network
  - IPv6 technology
  - WIA-PA standard
  - SDN
- Goal
  - Provide an SDN-based WIA-PA field network/IPv6 backhaul network joint scheduling method.
  - Enable the end-to-end joint scheduling of the cross-network data streams.
  - Enable the recognition of different types of cross-network data streams.
  - Enable the bandwidth guarantee specific to different types of cross-network end-to-end data.
  - Enable the acceleration of cross-network business deployment and reduce the management cost for network operation and maintenance.

Overview

- Joint Scheduling Architecture.

- Requirements.

- Method.

- Next steps

Network Structure

- A typical deterministic industrial field networks - backhaul networks structure.

- End-to-end joint scheduling of the cross-network data streams

```
+-------------------------------------------+
|                                           |
|                                           |
|             Backhaul network              |
|                                           |
|                                           |
+-------------------------------------------+
           /                     \
          /                       \
+-----------------------+   +-----------------------------+
|                       |   |                             |
|                       |   |                             |
|      Field network    |   |        Field network        |
|                       |   |                             |
|                       |   |                             |
+-----------------------+   +-----------------------------+
```
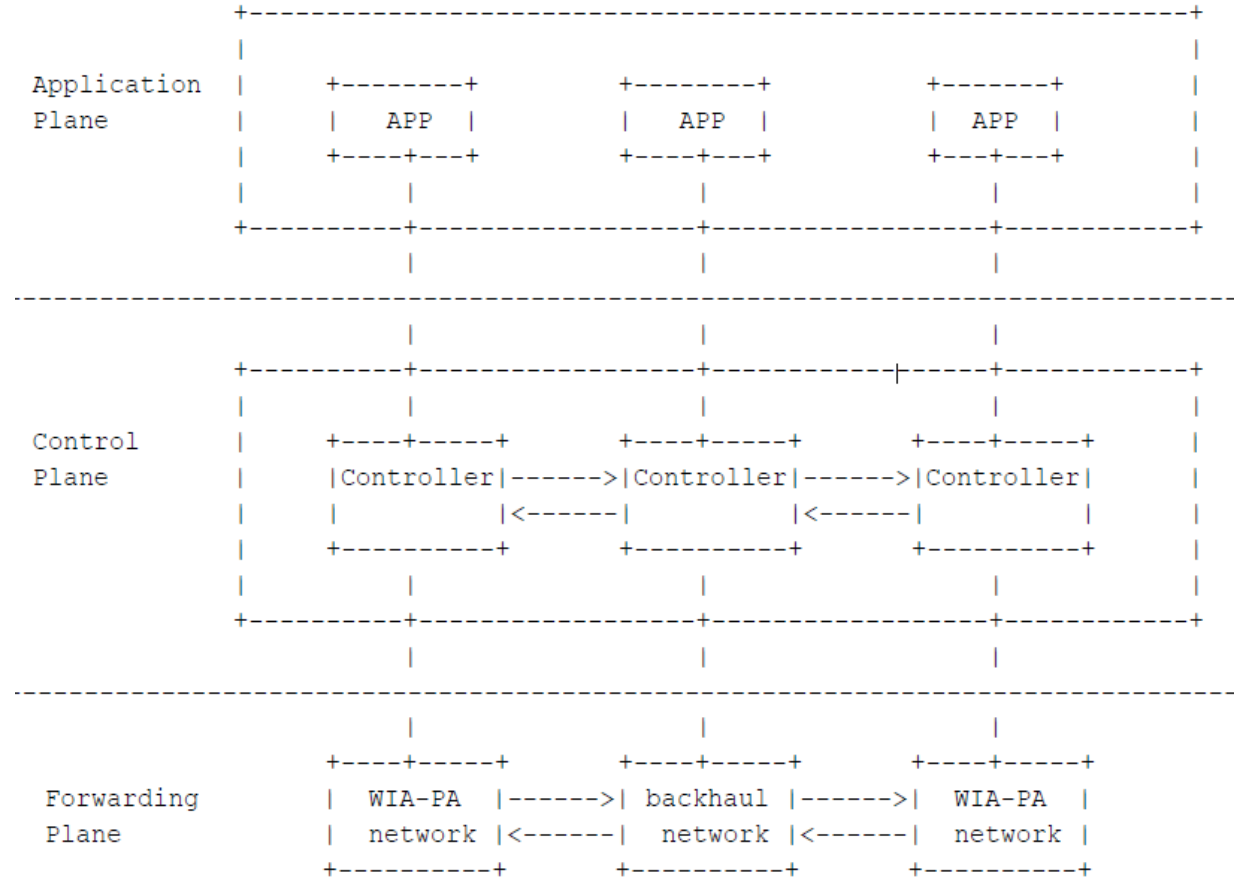
Joint Scheduling Architecture

- Control Plane
  - There are many network controllers in the network, which together constitute the control plane for the whole industrial network.

- No uniform standard
  - There is not a unified standard of joint architecture of multiple controllers in the industry at present.

- The main frameworks
  - Distributed architecture.
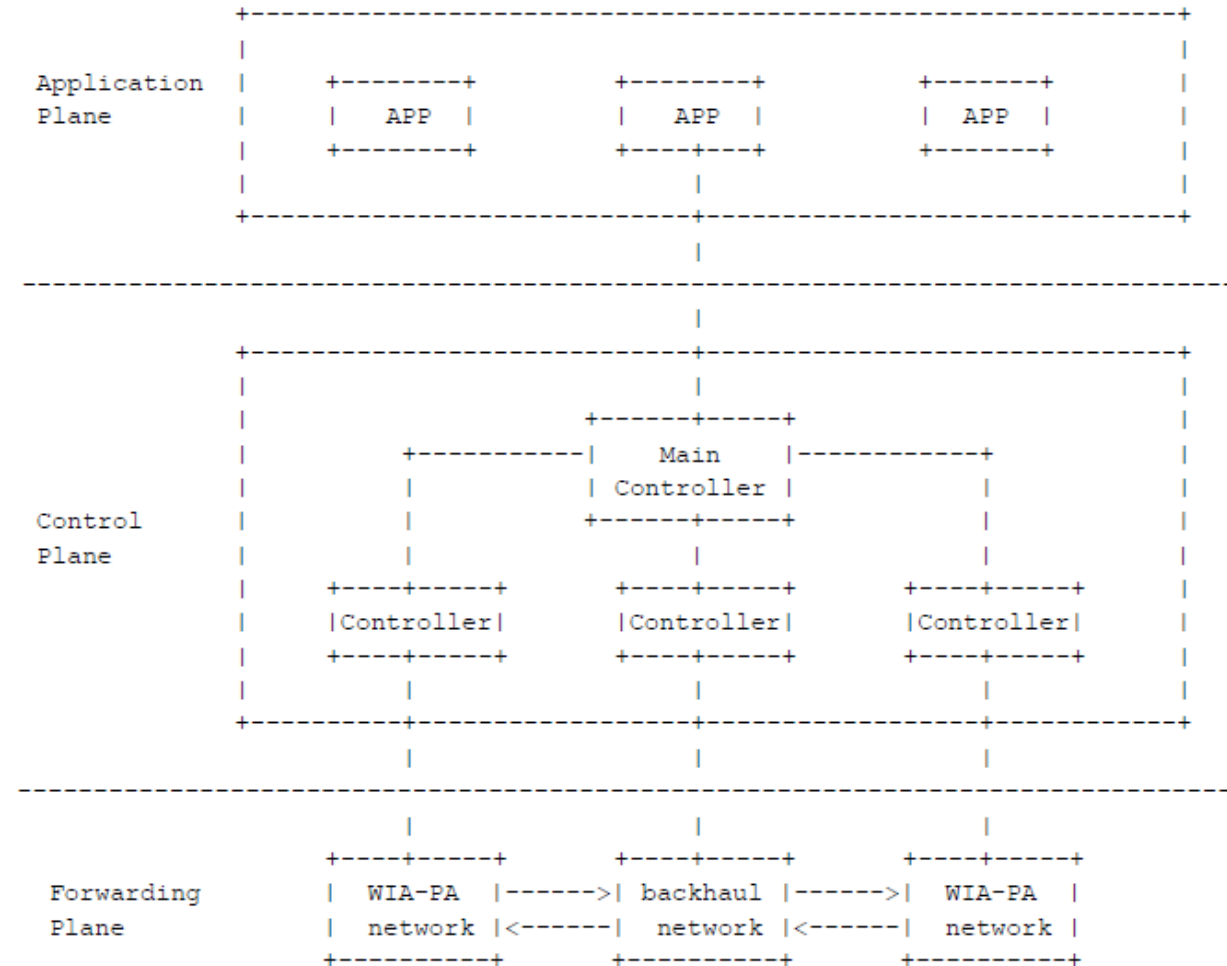 - Centralized architecture.

Joint Scheduling Architecture

- Distributed Architecture
  - East-West architecture.
  - The status of all network controller is equal.
- Disadvantages
  - Need to extend the east-west interface;
  - Maintain a global network topology in each controller.

```
         +--------------------------------------------------------+
         |                                                        |
Application |    +--------+        +--------+        +-------+     |
Plane    |      |  APP   |        |  APP   |        |  APP  |      |
         |      +----+---+        +----+---+        +---+---+      |
         |           |                |                 |         |
         +-----------+----------------+-----------------+---------+
                     |                |                 |
         -------------------------------------------------------------
                     |                |                 |
         +-----------+----------------+--------------+--+----------+
         |           |                |              |  |          |
Control  |    +----+-----+      +----+----+        +----+-----+    |
Plane    |    |Controller|----->|Controller|----->|Controller|    |
         |    |          |<-----|          |<-----|          |    |
         |    +----------+      +----------+        +----------+   |
         |         |                |                  |           |
         +---------+----------------+------------------+-----------+
                   |                |                  |
         -------------------------------------------------------------
                   |                |                  |
              +----+-----+      +----+-----+        +----+-----+
Forwarding    |  WIA-PA  |----->| backhaul |----->|  WIA-PA  |
Plane         |  network |<-----|  network |<-----|  network |
              +----------+      +----------+        +----------+
```
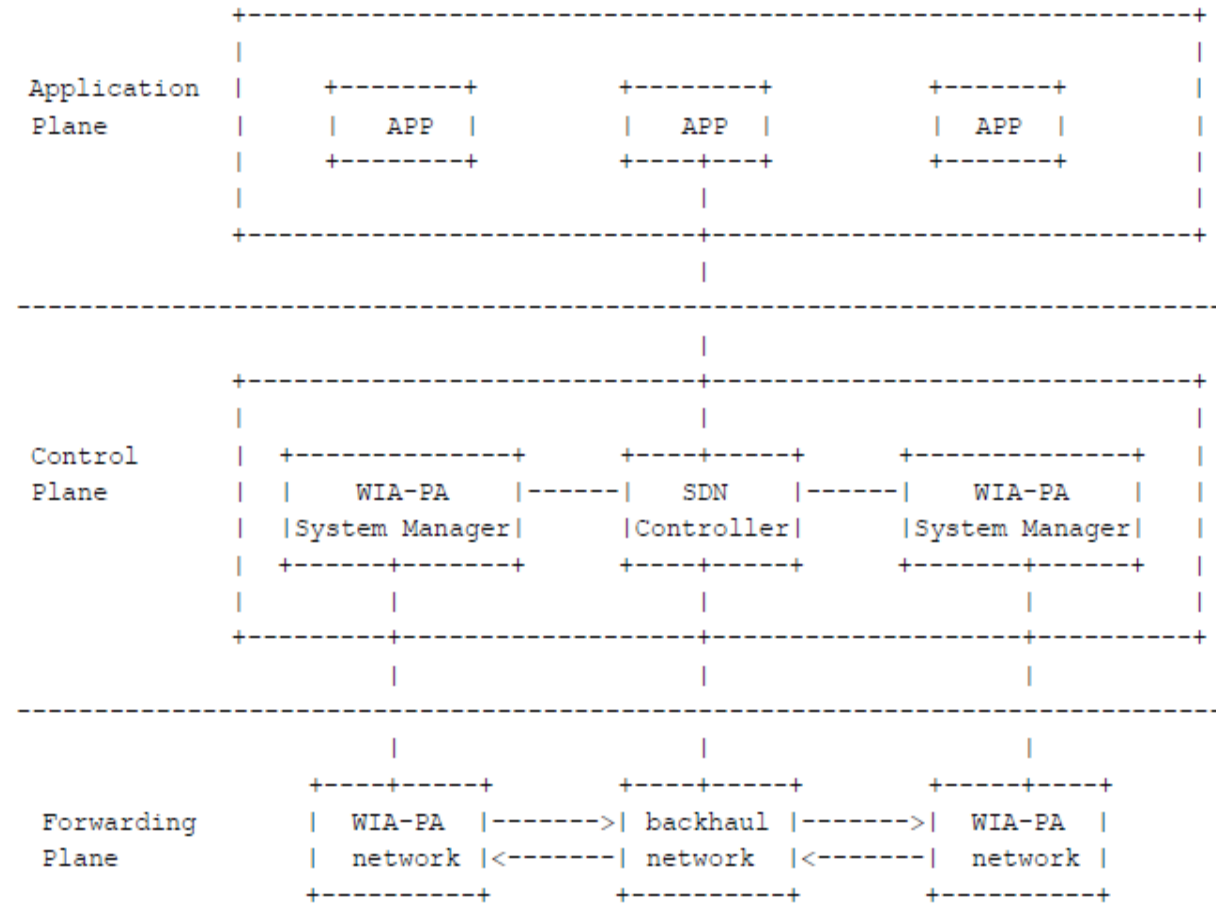
Joint Scheduling Architecture

- Centralized Architecture
  - Vertical multi-level architecture;
  - One is the basic control plane composed of a variety of network controllers;
  - Another part is a network controller composed of the main controller.

- Disadvantages
  - The scale of the network is not very large;
  - A single SDN controller is sufficient to meet the control demands of industrial backhaul network.

```
            +-------------------------------------------------+
            |                                                 |
Application |    +--------+       +--------+       +-------+   |
Plane       |    |  APP   |       |  APP   |       |  APP  |   |
            |    +--------+       +----+---+       +-------+   |
            |                          |                      |
            +-------------------------------------------------+
                                       |
            -----------------------------------------------------
                                       |
            +-------------------------------------------------+
            |                          |                      |
            |                    +-----+-----+                |
            |       +------------|   Main    |------------+   |
            |       |            | Controller|            |   |
Control     |       |            +-----+-----+            |   |
Plane       |       |                  |                  |   |
            |  +----+-----+       +----+-----+       +----+----+ |
            |  |Controller|       |Controller|       |Controller| |
            |  +----+-----+       +----+-----+       +----+----+ |
            |       |                  |                  |      |
            +-------------------------------------------+--------+
                    |                  |                  |
            -----------------------------------------------------
                    |                  |                  |
               +----+-----+       +----+-----+       +----+-----+
Forwarding     |  WIA-PA  |------>| backhaul |------>|  WIA-PA  |
Plane          |  network |<------|  network |<------|  network |
               +----------+       +----------+       +----------+
```

Joint Scheduling Architecture

- Control plane
  - WIA-PA System Manager, SDN controller.
  - Joint scheduler is integrated into the SDN controller in the form of plugin.
  - Establishing a connection with the SDN controller.
  - Directly calling the corresponding module of SDN controller.

- Joint Scheduling Architecture
  - Deterministic networks and deterministic Ethernet-based networks are jointly scheduling.
  - Control and scheduling for the entire industrial network by joint scheduler, so as to provide a real-time protection for each data stream.

```
                 +----------------------------------------------------------+
                 |                                                          |
Application      |    +--------+              +--------+          +-------+  |
Plane            |    |  APP   |              |  APP   |          |  APP  |  |
                 |    +--------+              +----+---+          +-------+  |
                 |                                 |                        |
                 +----------------------------------------------------------+
                                                   |
- - - - - - - - - - - - - - - - - - - - - - - - - -|- - - - - - - - - - - - -
                                                   |
                 +----------------------------------------------------------+
                 |                                 |                        |
Control          |   +-------------+         +----+-----+     +-------------+|
Plane            |   |   WIA-PA    |------|   SDN    |-----|   WIA-PA    ||
                 |   |System Manager|         |Controller|     |System Manager||
                 |   +------+------+         +----+-----+     +------+------+|
                 |          |                     |                 |       |
                 +----------+---------------------+-----------------+-------+
                            |                     |                 |
- - - - - - - - - - - - - - |- - - - - - - - - - -|- - - - - - - - -|- - - - -
                            |                     |                 |
                 +----+-----+         +----+-----+         +----+-----+
Forwarding       |  WIA-PA  |------->| backhaul |------->|  WIA-PA  |
Plane            | network  |<-------| network  |<-------| network  |
                 +----------+         +----------+         +----------+
```

Joint Scheduling Requirements

- Determinacy
  - The data of Industrial field network-backhaul network directly related to the monitoring and control of industrial production process.

- Time Synchronization
  - The industrial field/backhaul network is a converged network and need some scheduling methods to ensure deterministic data stream. So it requires high time synchronization accuracy between devices in the network.

- Compatibility
  - Some mechanisms, interfaces, etc. will be necessary when conducting joint scheduling to be compatibility with industrial field/backhaul network.

- Scalability
  - Data scalability should be ensured during joint scheduling process.

Joint Scheduling Method

- Solution
  - A joint controller, WIA-PA network managers, gateways and field devices;
  - The joint controller consists of an SDN controller and a joint scheduling plugin,
  - WIA-PA networks are uniformly managed by the joint controller;
  - The joint controller assigns a network identifier (PAN_ID) to each network manager connected thereto for identifying different WIA-PA networks;

Combined Controller

Data Transmission

Configuration Command

Network Controller

Network Controller

Gateway

Gateway

IPv6 Backhaul Network

WIA-PA Network
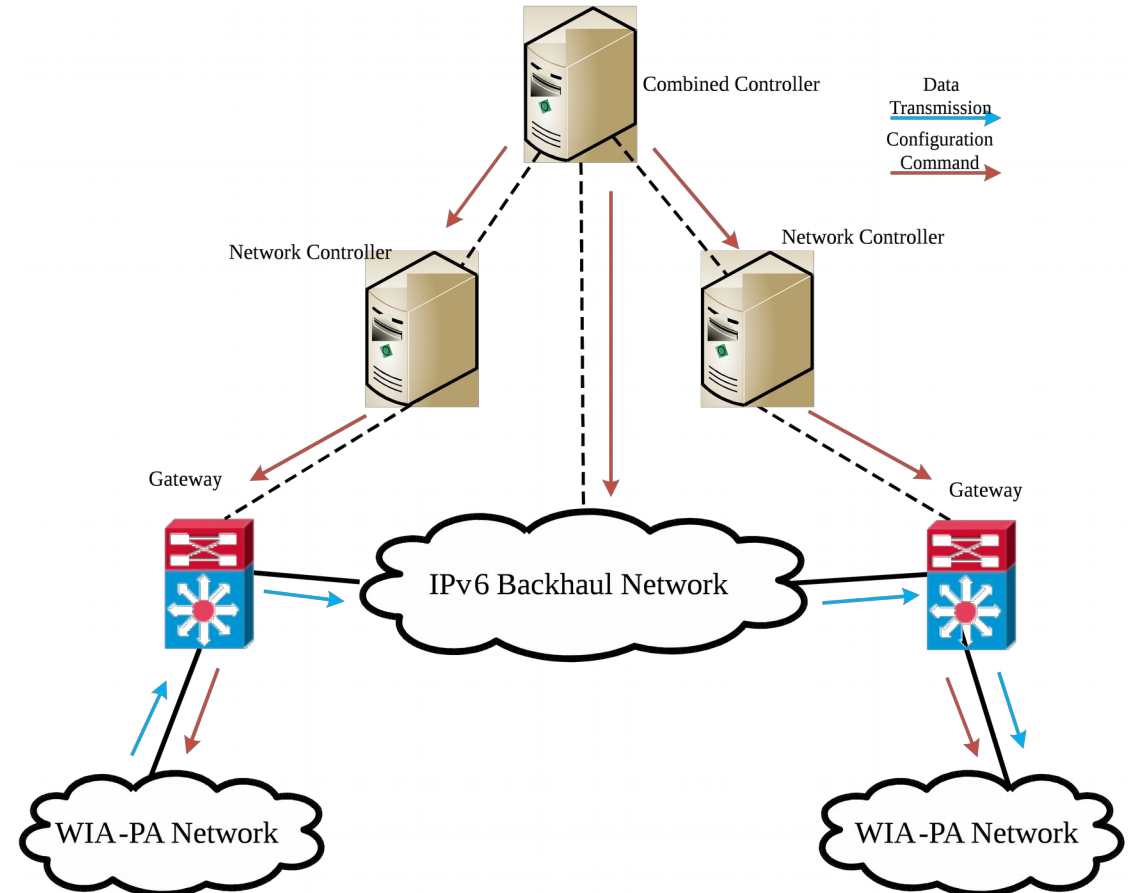
WIA-PA Network

A schematic diagram showing joint scheduling.

Joint Scheduling Method

- Establish backhaul network
  - S1: establishing a connection with the joint controller actively by the network managers ;
  - S2: collecting information of the WIA-PA networks periodically;
  - S3: receiving and analyzing a business establishing request by the joint controller;
  - S4: looking up the PAN_ID of a source node and a destination node according to analyzed information;
  - S5: looking up the information of the corresponding networks and nodes and assigning paths and resources;
  - S6: sending a path and resource configuration request;
  - S7: sending a mapping table of WIA-PA network addresses and IP addresses to the gateways;
  - S8: configuring the controlled IPv6 backhaul network.

Joint Scheduling Method

- The network access of a network manager
  - Step 1: establishing a connection with the joint controller and reporting network manager information;
  - Step 2: assigning one PAN_ID to the WIA-PA network and establishing a mapping relation;
  - Step 3: sending a request for getting topology information and node information;
  - Step 4: replying with the topology information and node information;
  - Step 5: sending a configuration completion to end a network access process.
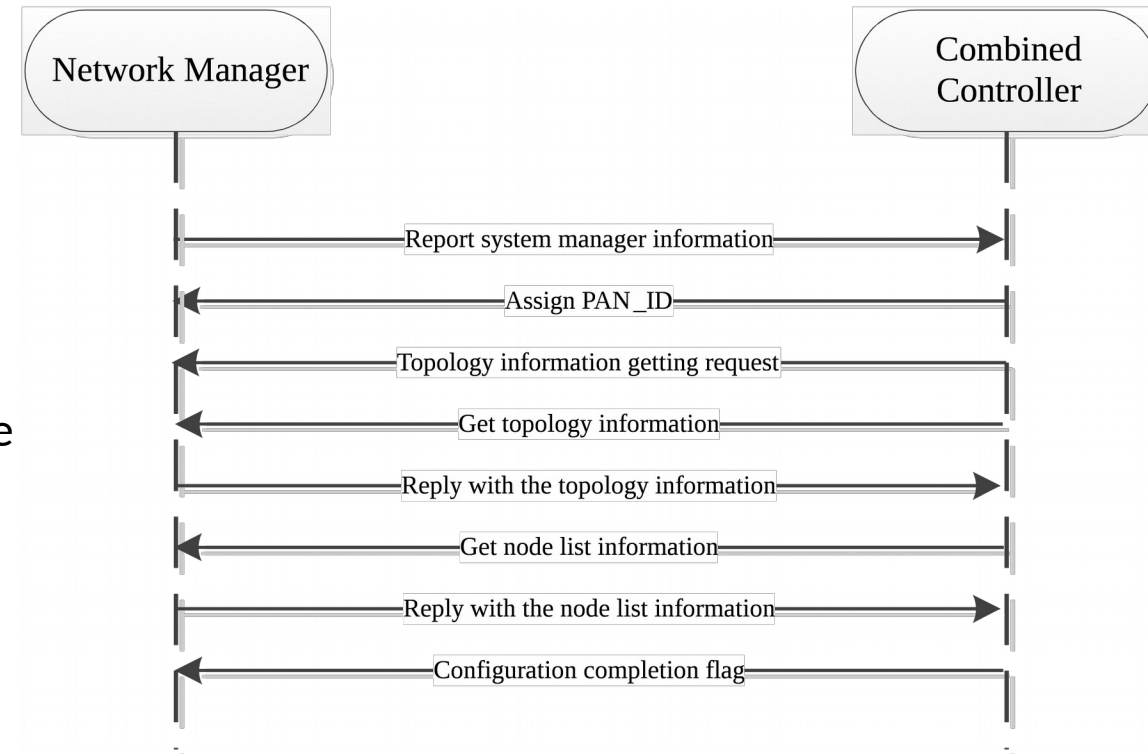
The network access of a network manager.

Joint Scheduling Method

- WIA-PA Network Joint Scheduling Scheme
  - Path deployment and resource allocation for WIA-PA network are performed by calling the WIA-PA network system manager API interface.
  - System manager query the corresponding information of the field device in the network
  - Then return the received information to the united scheduler.
  - Configure communication resources for the corresponding gateway device, routing equipment and field equipment.
  - Send a successful reply to the united scheduler after receiving a successful response.
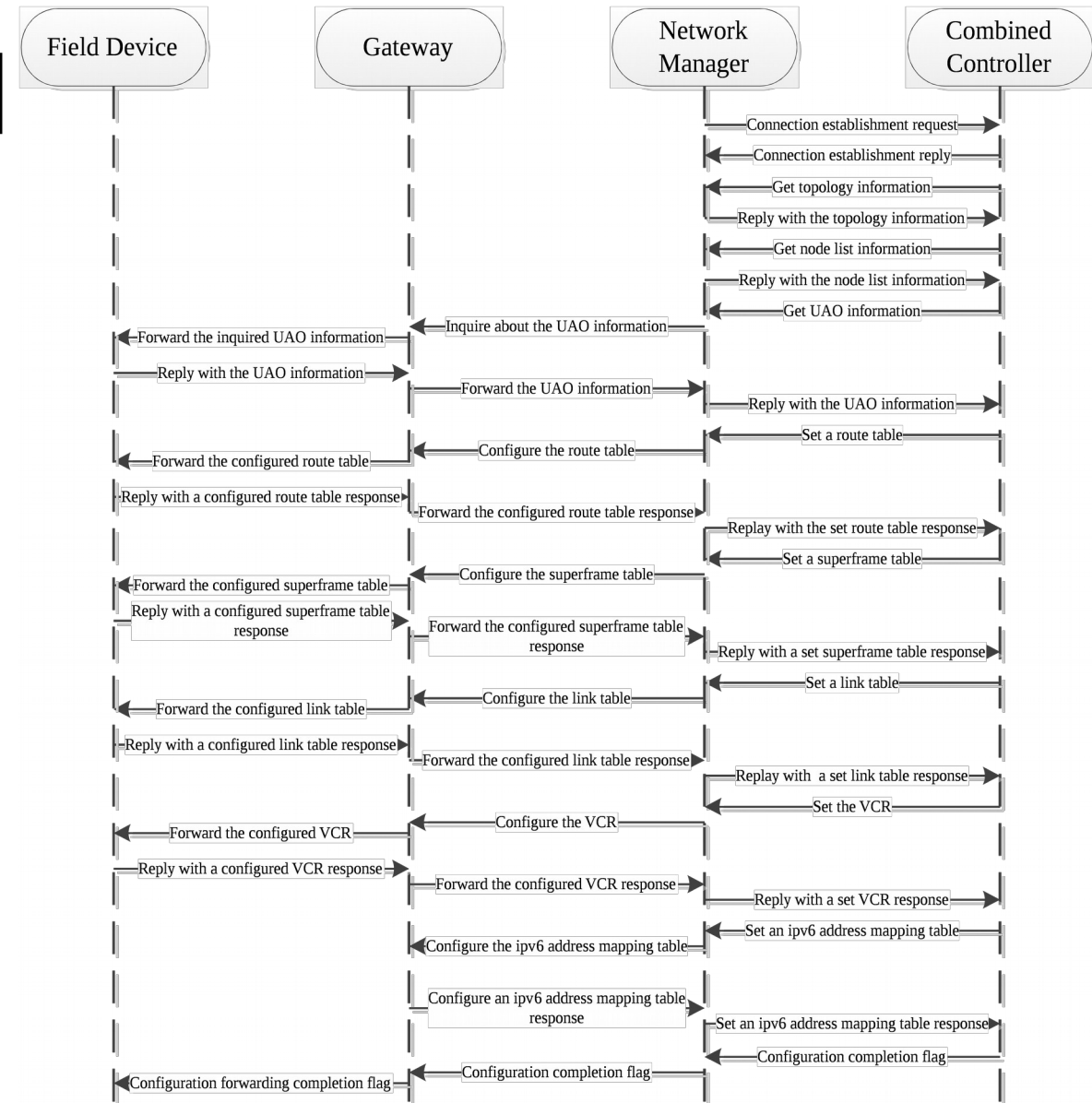
A joint scheduling configuration.

Joint Scheduling Method

- Gateway protocol conversion
  - Step 1: receiving a data packet and judging whether the data packet is management data by a gateway;
  - Step2: If so, forwarding the data packet to the network manager, otherwise looking up a VCR;
  - Step3: looking up an IPv6 address according to Route_ID by the gateway;
  - Step 4: encapsulating the WIA-PA data packet in an IPv6 format by the gateway.
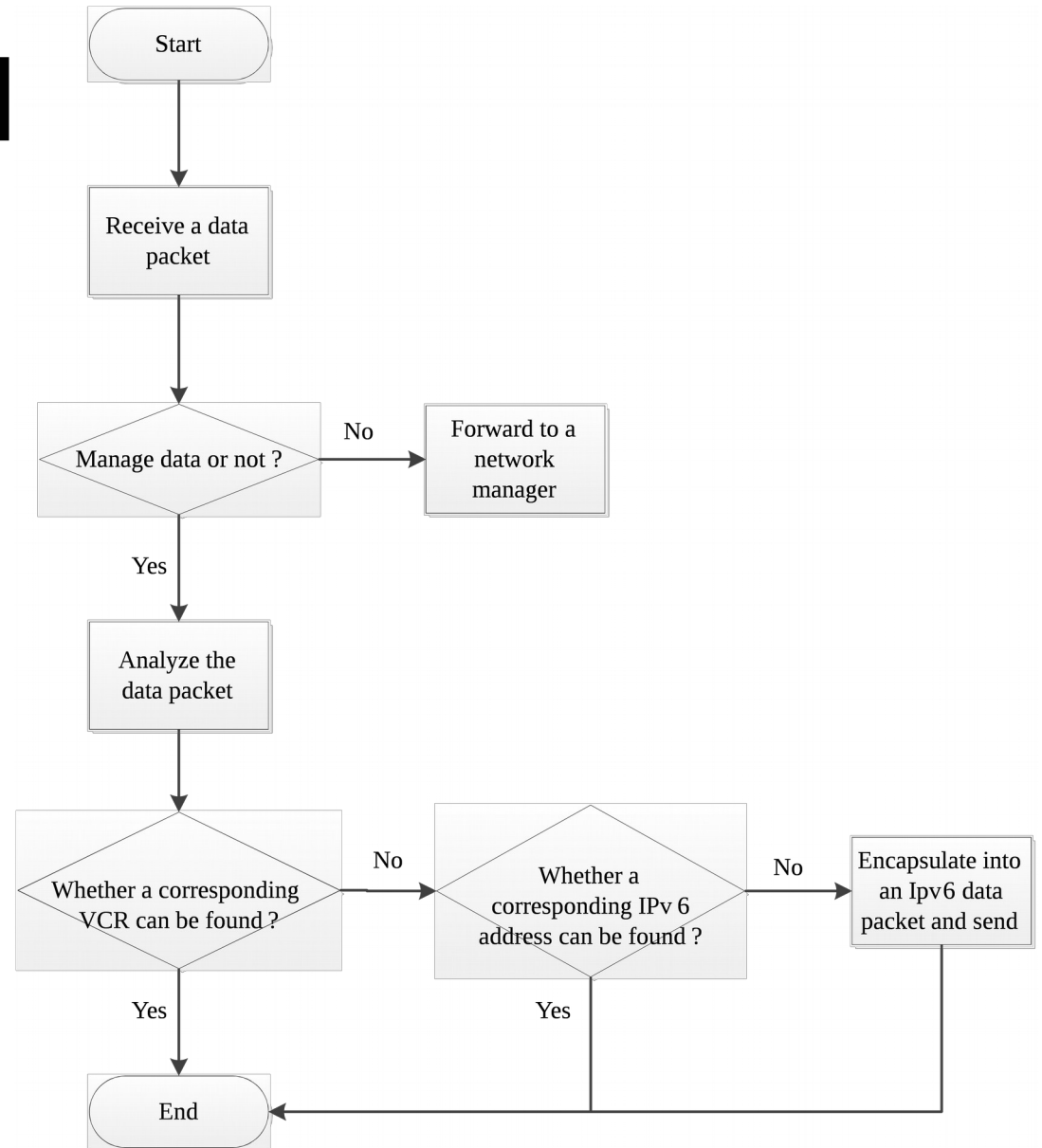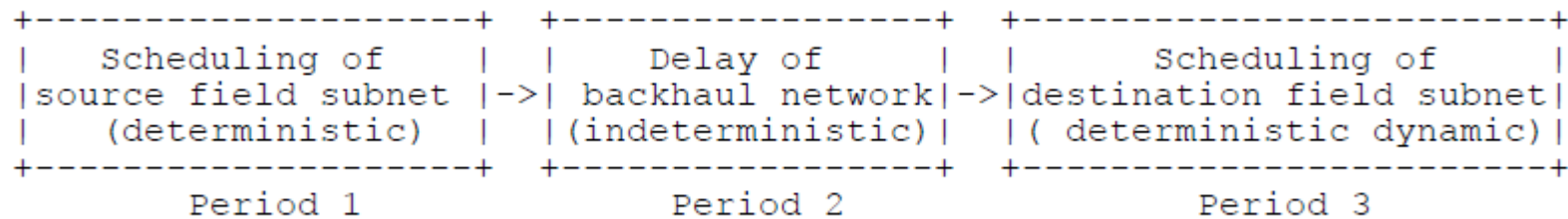

Gateway protocol conversion.

Joint Scheduling Method

- Bandwidth guarantee of the IPv6 backhaul network
  - Step 1: calculating path information and network resource assignment;
  - Step 2: verifying whether a bandwidth in the path is sufficient for meeting a business;
  - Step 3: if so, deploying a flow table through the SDN controller;
  - Step 4: if not, recalculating the path information and resource assignment and selecting other secondary paths.
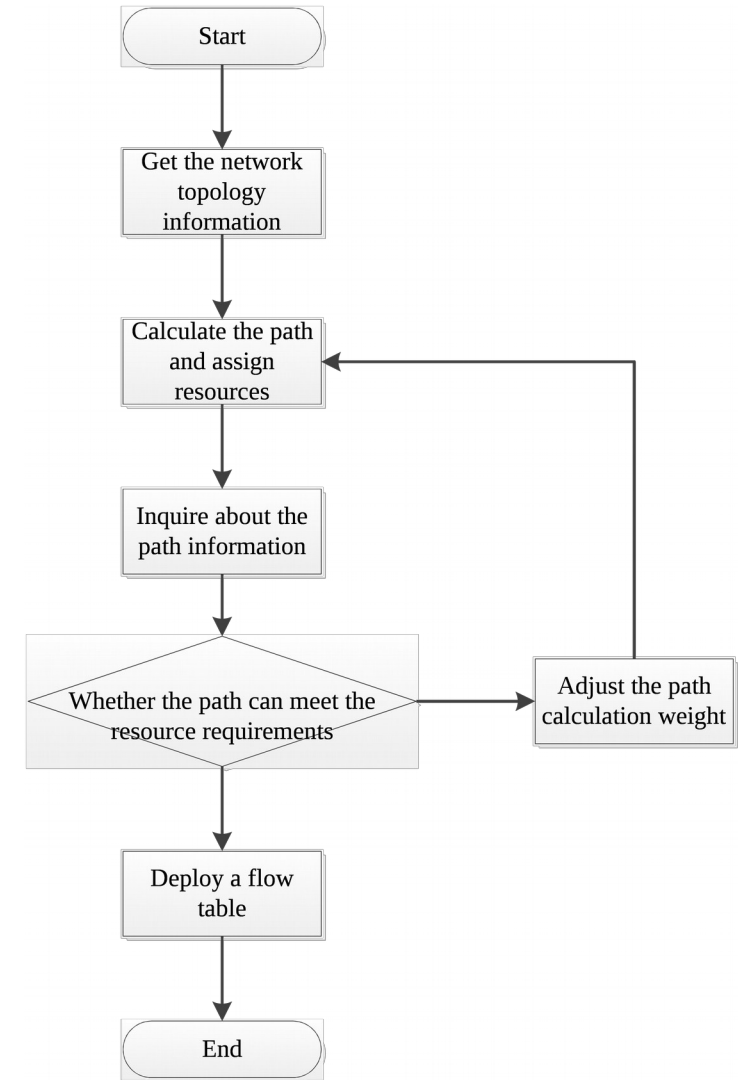
The bandwidth guarantee for an IPv6 backhaul network

Joint Scheduling Method

- Consider Industrial Backhaul Network as a Black Box
    - Only consider its delay impacts and ignore its internal details.
    - The approximate delay of packets caused by the industrial backhaul network.
    - Implementing a few of scheduling paths of different priority.
    - Then the data stream goes through the black box, and it will cause uncertain delay which is in a numerical range.
    - When the data stream comes out the backhaul network.
      (the deadline is missed / there is time left)

```
+--------------------+   +-----------------+   +------------------------+
|    Scheduling of   |   |     Delay of    |   |      Scheduling of     |
|source field subnet |->| backhaul network|->|destination field subnet|
|   (deterministic)  |   | (indeterministic)|   |( deterministic dynamic)|
+--------------------+   +-----------------+   +------------------------+
      Period 1                 Period 2                 Period 3
```

Next steps

- Ignore the Delay of Industrial Backhaul Network
- Build Delay Model of Industrial Backhaul Network

Thanks!

Heng Wang, Ping Wang, Lun Shao

wangheng@cqupt.edu.cn, wangping@cqupt.edu.cn, yjssslcqupt@163.com

Chongqing University of Posts and Telecommunications , China

Chicago, March 27, 2017