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SERIES Q: SWITCHING AND SIGNALLING, AND ASSOCIATED MEASUREMENTS AND TESTS

Signalling requirements and protocols for SDN – Resource control protocols

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Signalling requirements of SDN-based access networks with media-independent management capabilities

Recommendation ITU-T Q.3714

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Recommendation ITU-T Q.3714

Signalling requirements of SDN-based access networks with media-independent management capabilities

Summary

Recommendation ITU-T Q.3714 provides signalling architecture, signalling requirements and signalling protocol procedures for SDN-based access networks with media independent management (MIM) capabilities. It defines signalling architecture models of SDN-based access networks with MIM capabilities. The signalling architecture models are described for loosely and tightly coupled integrations between SDN and MIM control frameworks. Signalling requirements and protocol procedures for resource management and seamless handover are described for each signalling architecture model.

History

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Media independent management, MIM, SDN, software-defined networking.

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Recommendation ITU-T Q.3714

Signalling requirements of SDN-based access networks with media-independent management capabilities

1 Scope

This Recommendation describes the signalling architecture, signalling requirements and signalling protocol procedures for SDN-based access networks with media independent management (MIM) capabilities. This document introduces signalling architecture models of SDN-based access networks with MIM capabilities. The signalling architecture models are described for loosely and tightly coupled integrations between SDN and MIM control frameworks. Signalling requirements and protocol procedures for resource management and seamless handover are described for each signalling architecture model.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T Y.3300] Recommendation ITU-T Y.3300 (2014), *Framework of software-defined networking.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 access network [b-ITU-T Q.1742.11]: Network that connects access technologies (such as a radio access network) to the core network.

3.1.2 candidate network [b-IEEE 802.21]: A network that is a potential target to the mobile node's movement.

3.1.3 mobile node (MN) [b-IEEE 802.21]: Communication node that is capable of changing its point of attachment from one link to another.

3.1.4 seamless handover [b-IEEE 802.21]: A handover associated with a link switch between points of attachment, where the mobile node either experiences no degradation in service quality, security, and capabilities, or experiences some degradation in service parameters that is mutually acceptable to the mobile subscriber and to the network that serves the newly connected interface.

3.1.5 serving network [b-IEEE 802.21.1]: A network that provides services to the user. The serving network can be a home subscriber network or a visited network.

3.1.6 software-defined networking [ITU-T Y.3300]: A set of techniques that enables to directly program, orchestrate, control and manage network resources, which facilitates the design, delivery and operation of network services in a dynamic and scalable manner.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 media independent management (MIM): A management mechanism that allows the control of the link layer and the acquisition of information from the link layer in a media independent way, by providing a generic interface between the higher layers and the media-specific link layers for different types of media (i.e., wired twisted pair copper, wired optical fibre, wireless radio, etc.). It provides generic link-layer intelligence and other network resources information independent of the specifics of mobile nodes or radio networks.

3.2.2 media independent management (MIM) function (MIMF): A function that realizes MIM capabilities.

3.2.3 media independent management (MIM) user: An entity that uses the capabilities provided by the MIM function.

3.2.4 MIMF-enabled access point: An access point that has an MIM function.

NOTE – An MIM function can be implemented in WLAN AP or the base station in a cellular network.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AP	Access Point
API	Application Program Interface
AT	Access Technology
ID	Identifier
L1	Layer 1 (physical layer [PHY])
L2	Layer 2 (medium access control [MAC] and/or logical link control [LLC])
LAN	Local Area Network
LTE	Long-Term Evolution
MAC	Media Access Control
MIM	Media Independent Management
MIMF	Media Independent Management Function
MIS	Media Independent Service
MISF	Media Independent Service Function
MN	Mobile Node
MTCP	Multipath TCP
NIC	Network Interface Card
ONF	Open Network Foundation
PHY	Physical Layer
PoS	Point of Service
QoS	Quality of Service
RAN	Radio Access Network
REST	Representational State Transfer

SAP	Service Access Point
SDMN	Software-Defined Mobile Network
SDN	Software-Defined Networking
SDRAN	Software-Defined Radio Access Network
TCP	Transmission Control Protocol
VLAN	Virtual LAN
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network

5 Conventions

None.

6 Signalling architecture of SDN-based access networks with MIM capabilities

Software-defined networking (SDN) is based on the separation of control and data planes with a logically centralized controller. High-level SDN architecture consists of application layer, SDN control layer, resource layer, and multi-layer management functions. See [ITU-T Y.3300]. There are two interfaces in the high-level architecture of SDN: the application-control interface called northbound interface and the resource-control interface called southbound interface. In SDN, a logically centralized controller uses a southbound interface to manage and control the underlying data plane, and configures the forwarding table of the switches. The logical centralized controller also uses a northbound protocol to enable the possibility of creating a centralized view of the network, simplify the control operations through service-oriented application program interfaces (APIs) (e.g., northbound interface), and accelerate change and innovation in the control plane. The information about how packets and flows are treated is exchanged among the network entities and stored on the forwarding table. Thus, network operations, such as routing and forwarding decisions, are centralized by the central control entity in the network, which allows more dynamic network topology (re)configuration and flexible operations. The southbound protocol (e.g., OpenFlow protocol) was primarily designed for network control operations using the southbound interface in wired core network environments. The protocol lacks, however, optimized mechanisms to manage wireless links. In wireless environments, management of the links is more challenging in configuration and resource allocation due to the mobility of users (e.g., handover) and relatively unstable wireless link conditions (e.g., interference) compared to wired ones.

The basic operations of SDN mentioned above mostly target fixed wired links but do not consider wireless link conditions when employing their controlling mechanisms. The dynamic wireless link conditions are important for the optimized usage of wireless resources. Hence, It is necessary to extend the SDN operations for wireless access networking, by allowing the SDN controller to control and manage wireless links through a set of MIM mechanisms for obtaining wireless link information and controlling wireless link behaviour, in an access technology agnostic way. In this way, the SDN will be able to provide a common optimized control for wired and wireless networks.

The MIM mechanism consists of the MIM function (MIMF), MIM message and MIM user. The MIM function provides a generic interface between the different link layer technologies and the upper layers. A set of MIM messages, which is common for the different link layer technologies, is used to collect link information and status, and to support seamless handover and resource management functions. An MIM user interacts with the MIM function in the same network entity by sending or receiving MIM messages, and decides whether to use the MIM message information for itself or forward it to another MIM user or MIM function of other network entity.

The aim of this Recommendation is to provide signalling requirements of the SDN-based access networks with MIM capabilities, and to describe SDN control framework models, either interworking with or integrated with the MIM to support signalling scenarios related to radio resource allocation and seamless handover.

In the following subclauses, we define and describe network architecture and signalling architecture of the SDN-based access networks with MIM capabilities. Clause 6.1 describes the network architecture of SDN-based access networks with MIM capabilities. Clause 6.2 describes one decoupled model and clause 6.3 describes two integration models (i.e., loosely and tightly coupled integration models) of the SDN-based access networks with MIM capabilities.

a) Network architecture of SDN-based access network with MIM capabilities

To support link resource management and seamless handover in SDN-based access networks with MIM capabilities, network architecture, signalling requirements and message flows should be defined. For that purpose, this subclause describes a network architecture under consideration.

Figure 6-1 shows the network architecture of SDN-based access networks with MIM capabilities. As network entities, this figure illustrates both an MIMF-enabled SDN switch integrated with access point (AP in WLAN, base station in cellular network) and an MIMF-enabled SDN switch separated from the MIMF-enabled access point. The MIM controller function can reside in the SDN controller as shown in this figure, or be located outside the SDN controller. A mobile node (mobile node 1), which is attached to an MIMF-enabled SDN switch integrated with the access point of a serving network, will move and be attached to one of the MIMF-enabled SDN switches integrated with an access point (candidate 1 and candidate 2) when handover occurs. The SDN controller with MIM controls and manages resources of all of APs and SDN switches of serving and candidate networks.

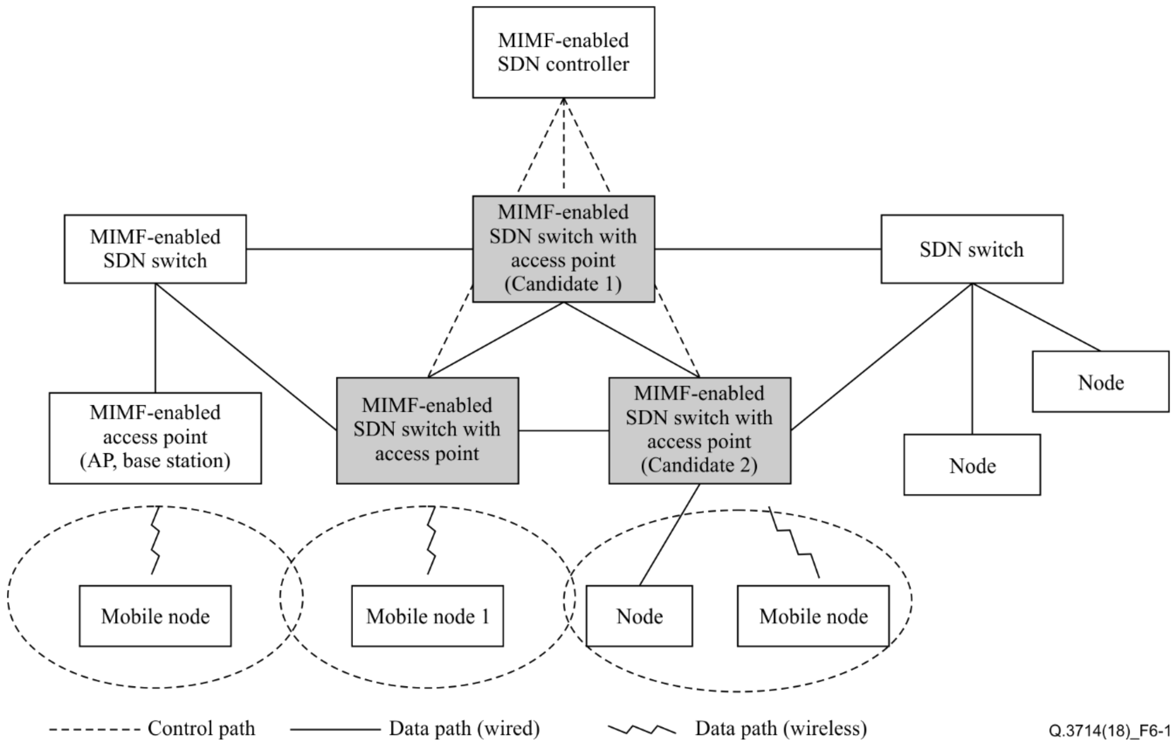

Figure 6-1 – Network architecture of SDN-based access network with MIM capabilities

b) Signalling architecture for decoupled interworking framework of SDN and MIM control

Figure 6-2 depicts the signalling architecture model of a decoupled approach for the interworking framework of SDN with MIM control. This decoupled approach uses both pre-existing SDN and pre-existing MIM protocols (e.g., [b-IEEE 802.21.1]) without any modification for the dynamic optimized support of SDN data path establishment and wireless connectivity establishment. This approach allows both SDN and MIM control functions to evolve independently by the separation of MIM control from SDN control. However, it forces network entities to support both protocols in parallel and will cause a large overhead in power consumption and complexity of network entities.

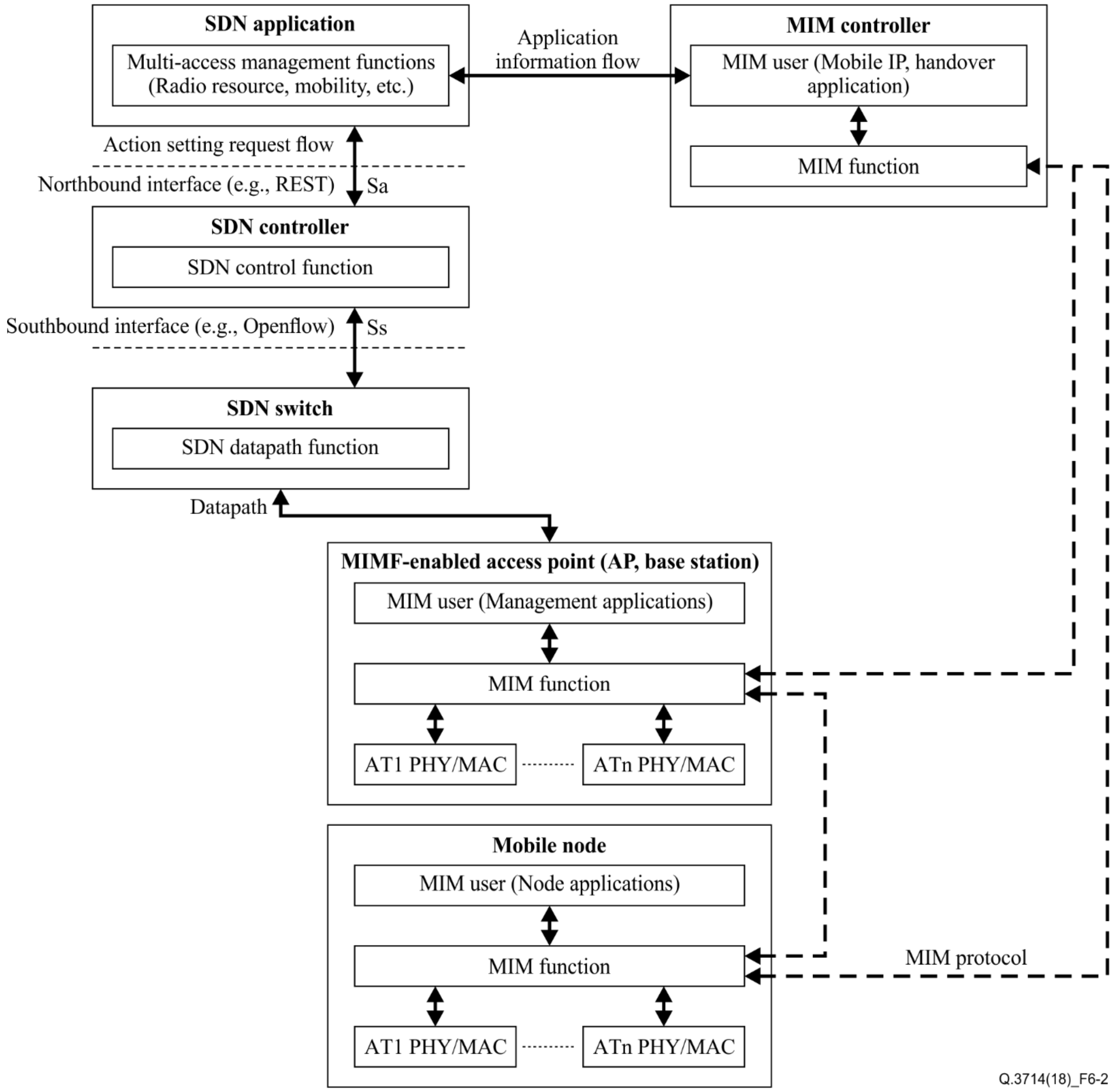

Figure 6-2 – The signalling architecture model of a decoupled approach for the interworking framework of SDN with MIM control

The signalling architecture model depicted in Figure 6-2 shows functions and functional interactions among the following network entities:

– SDN application: This network entity is responsible for handling network resources and controlling mobility procedures.

– SDN controller: This network entity is responsible for performing configuration, resource allocation, routing and switching related tasks, such as updating forward tables of SDN switches.

– SDN switch: This network entity is responsible for executing data packet forwarding operations, via a flow table which stores information on how to process each data flow, and network resources configured by an external entity (i.e., the SDN controller), via the southbound protocol.

– MIM controller (e.g., IEEE 802.21's point of service (PoS)): It has an MIM function for exchanging MIM protocol messages (for example, IEEE 802.21 messages) with other network entities.

– MIMF-enabled access point (e.g., AP in WLAN, Base station in cellular): It provides link connectivity to an MN, as well as featuring an MIM function. The MIM function communicates with its MIM user (management applications) module and its link interfaces.

– Mobile node (MN): The MN represents the end-user equipment that allows the user to connect to the network. The MN may have one or more access technology (AT), which can be wired (e.g., Ethernet) or wireless (e.g., WLAN, WiMAX, LTE). The MN's MIM function interfaces towards the access links and interfaces towards higher-layer entities, allowing them to control and to retrieve information from the links in an abstract way. This interfacing can be done by MN's MIM user (node applications) module or by external network entities (e.g., IEEE 802.21's PoS) that interface in a remote way via the MIM protocol. As such, the MN is able to provide events about detected MIM access points or events indicating that the current MIMF-enabled access point's signal level is decreasing past a predefined threshold, as well as to receive commands to execute handovers to other MIMF-enabled access points (e.g., where SDN already pre-established flow configuration).

One example of this decoupled interworking model of SDN and MIM control is the software-defined radio access network (SDRAN) use case in IEEE 802.21.1-2017 standard [b-IEEE 802.21.1]. See Appendix I on related works.

c) Signalling architecture for integrated framework of SDN and MIN controls

6.1 Loosely-coupled integration of SDN and MIM control frameworks

Figure 6-3 depicts the signalling architecture model of a loosely-coupled approach for the integration of SDN and MIM control frameworks. Like the decoupled approach, this loosely-coupled approach uses both pre-existing SDN and pre-existing MIM protocols for the dynamic optimized support of SDN data path establishment and wireless connectivity establishment. However, in this approach, the MIM functional entities in MIMF-enabled SDN controller and MIMF-enabled SDN switch (or MIMF-enabled SDN switch & access point) communicate with each other through an SDN protocol channel. Hence, the SDN protocol between the MIMF-enabled SDN controller and the MIMF-enabled SDN switch (or MIMF-enabled SDN switch & access point) contains and transports the MIM protocol messages by simply encapsulating the MIM messages into the SDN protocol frame. This approach requires some additional parameter definitions in the pre-existing fields of the SDN protocol frame to indicate and locate the encapsulated MIM messages in the frame.

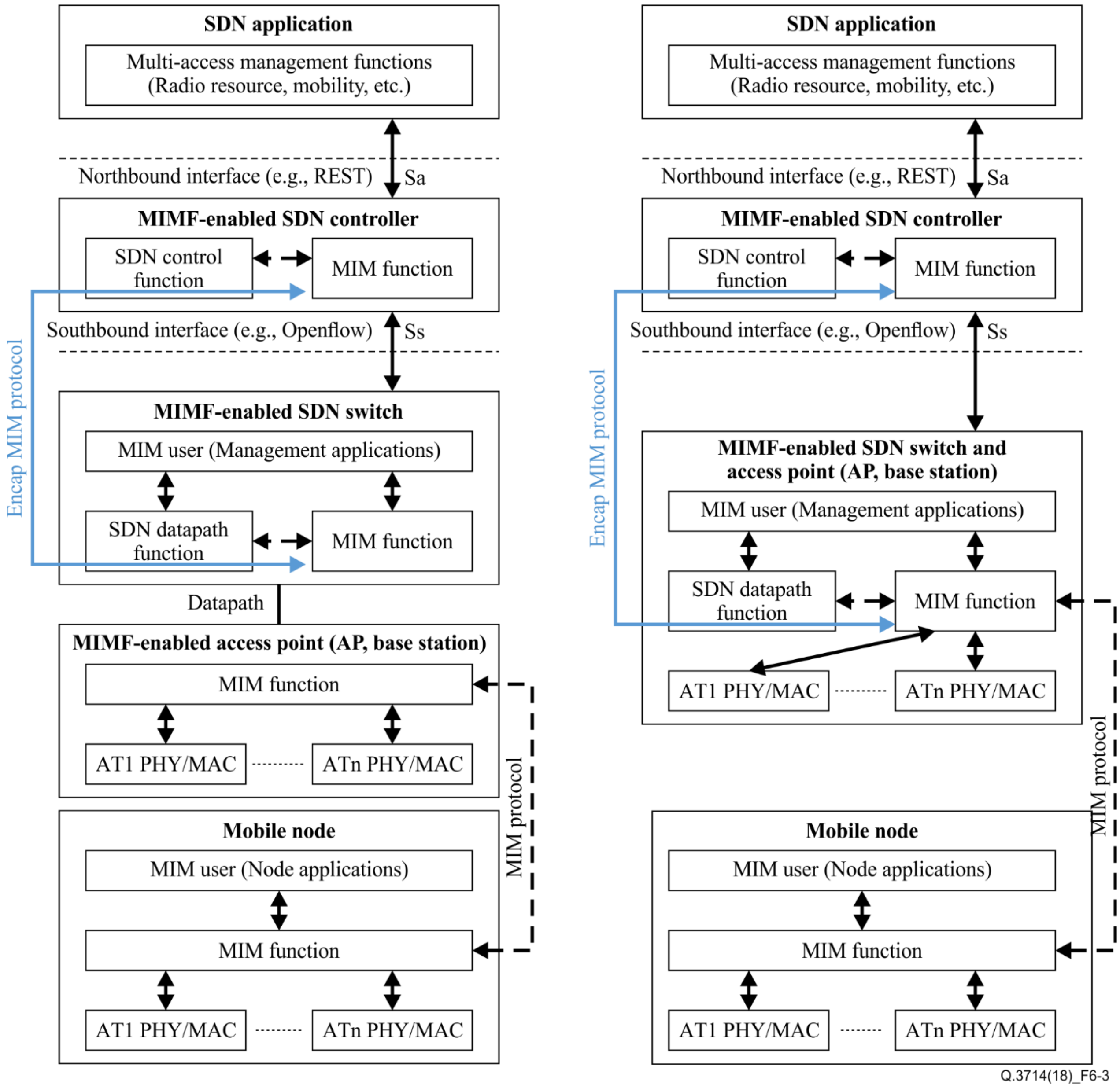

Figure 6-3 – The signalling architecture model of a loosely-coupled approach for the integration of SDN and MIM control frameworks

6.2 Tightly-coupled integration of SDN and MIM control frameworks

The MIM control framework allows the control and acquisition of information from the link layer in a media independent way by providing a generic interface between the higher layers and existing media-specific link layers. It can be applied to both wired and wireless technologies, due to the technology agnostic capability of the MIM framework.

Tightly-coupled integration architecture aims to embed the flexibility of MIM mechanisms into SDN protocol and SDN network functions in the network entities such as SDN controller and SDN switch. By coupling MIM mechanisms into the southbound protocol and network functions, a single control plane is provided for MIMF-enabled optimization of wireless connectivity without requiring multiple different protocols that increase node design complexity, and can be used to optimize network resources by allowing the network to reconfigure and to adapt itself dynamically based on the conditions of its links in SDN framework environment.

Figure 6-4 depicts the signalling architecture model of a tightly-coupled approach for the integration of SDN and MIM control frameworks. This tightly-coupled approach requires the development of

SDN protocol (for example, OpenFlow) extensions to obtain link information and to control link behaviour in a technology abstraction way. This architecture allows the SDN controller to control and manage wireless links through a set of MIM mechanisms, and the extended SDN protocol becomes able to provide a common optimized control of wired and wireless networks through SDN mechanisms.

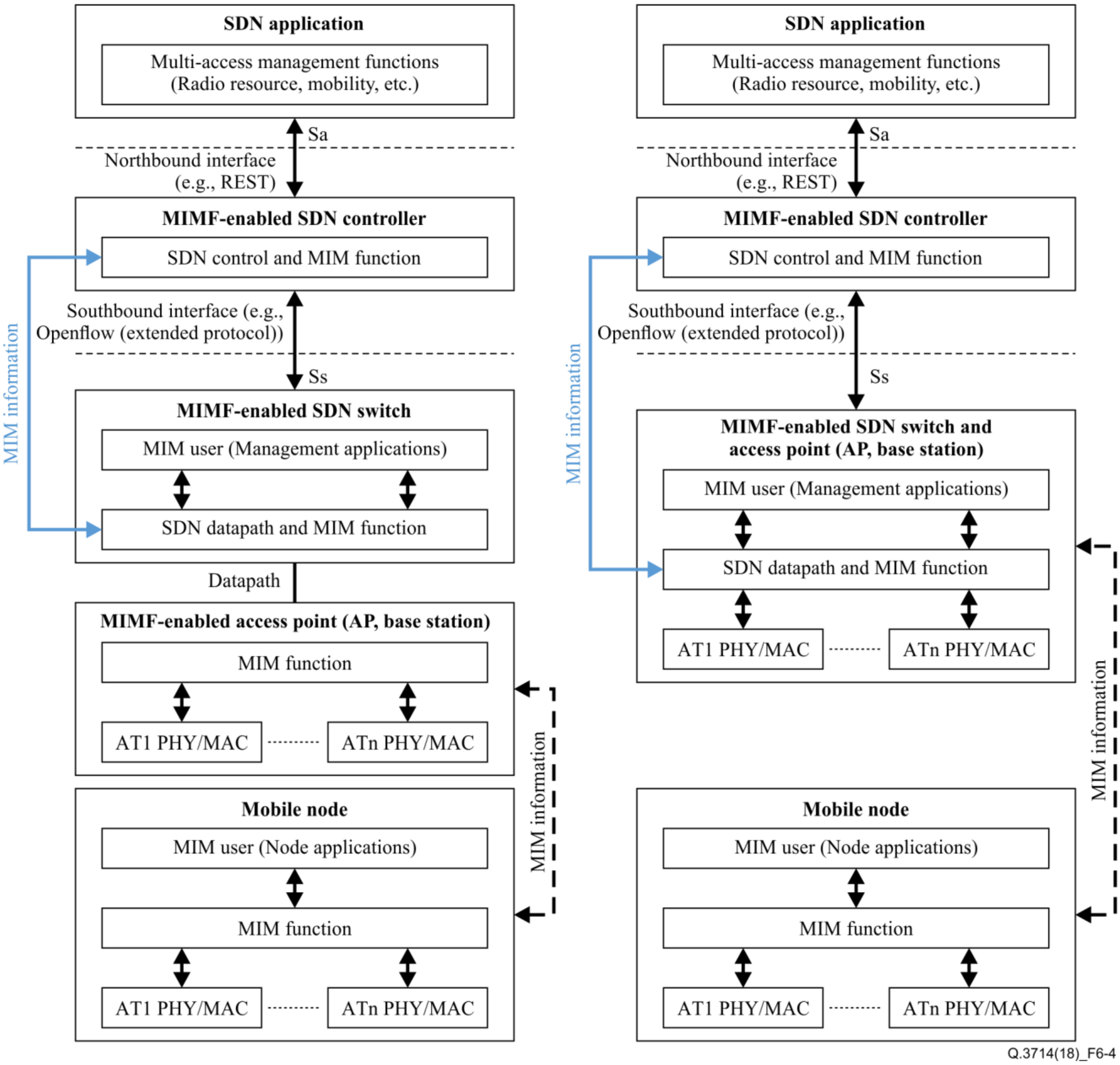

Figure 6-4 – The signalling architecture model of a tightly-coupled approach for the integration of SDN and MIM control frameworks

7 Signalling requirements of SDN-based access networks with MIM capabilities

This clause defines and describes signalling requirements including messages and primitives to support link resource management and seamless handover in SDN-based access networks with MIM capabilities. These signalling requirements are defined for the signalling architecture models of loosely-coupled and tightly-coupled integrations of SDN and MIM control frameworks. The signalling requirements for the decoupled interworking model described in clause 6.2 is out of the scope of this Recommendation.

a) Overview of signalling requirements

To support link resource management and seamless handover, the following messages related to wireless link are required in SDN-based access networks with MIM capabilities.

- Link_Discovery
- Link_Set_Configure
- Link_Get_Parameters
- Link_Actions
- Link_Event_Subscribe
- Link_Event_Unsubscribe
- Link_Probe
- Node_Attached
- Node_Detached

All of the messages consist of the message header and the payload. The message header format is described in Table 7-1.

Table 7-1 – Message header fields

Field name	Description
Version	This indicates the version of the message format
Message type	This uniquely specifies the type of message
Message length	This specifies the length of total message
Transaction ID	This is generated by the sender of the message and used to control the transaction of messages and matching of requests and responses

The transaction ID is used to control the transaction of messages. Transaction ID is associated with a message. If there is a response message for the request message, the transaction IDs of the request and response messages are the same. The response message uses the same ID as was in the request message to facilitate pairing.

As shown in Table 7-2, message payload contains operation code, source ID, destination ID, and optional information. The optional information field of a specific message may include some of the following parameters:

- Link address list: contains pairs of link ID and link address;
- Link ID: identifies the link of switches and APs;
- Node address: indicates link-layer address of a node;
- Status: result status of operation requested by Link_Discovery, Link_Set_Configure, Link_Actions, Link_Event_Subscribe/Unsubscribe, or Link_Probe;
- Link configuration list: contains link configuration parameters such as link type, link availability and link quality;
- Event list: contains list of events to be subscribed/unsubscribed, which are relevant to link status monitoring;
- Action list: contains list of actions to be taken for the control of the behaviour of the links, which are relevant to handover.

Table 7-2 – Message payload fields

Field name	Description
Operation code	This specifies a type of operation to be performed. As type of operation there are request, response and notify.
Source ID	This identifies the invoker of this message. It specifies the MIM function of the mobile node, SDN switch or SDN controller.
Destination ID	This identifies the receiver of this message. It specifies the MIM function of the mobile node, SDN switch or SDN controller.
Optional information	This field can contain optional parameters such as link address list, link ID, node address, status, link configuration list, event list and action list.

b) Signalling requirements for link discovery

Link_Discovery messages are used by the SDN controller to discover the link technology and to support capabilities of a specific link in the SDN switch. When invoking this message to discover the link of an SDN switch, the SDN switch can optionally transmit the link information of its mobile node. Therefore, it is possible to selectively transmit the information when the same node is found in two switches.

Table 7-3 – Payload optional information of 'Link Discovery' message

Optional information of request message	Optional information of response message
None or link ID	Link address list Status (link up/down/going-down information)

c) Signalling requirements for setting link configuration

Link_Set_Configure messages are used by the SDN controller to configure one or more parameter values (link type, link identifier, link availability, link quality, etc.) in the SDN switch. This request message is generated by an SDN controller to set configuration values for different link parameters in the SDN switch.

Table 7-4 – Payload optional information of 'Link Set Configure' message

Optional information of request message	Optional information of response message
Link ID Link configuration list	Link ID Status (configuration related information)

d) Signalling requirements for getting link parameters

Link_Get_Parameters messages are used by the SDN controller to discover and monitor the status of the links in the SDN switch. This message is also generated at specified intervals for various parameters and indicates changes in link conditions that have crossed specified levels. In the case of a wireless network, this event is generated when higher protocol layers wish to monitor the performance parameters for a network. These higher layers can be on the network side for network initiated handovers, and the MIM user (node applications) on the mobile node can transfer these parameters. For mobile node initiated handovers, the local MIM user (node applications) would monitor link-layer properties. For each specified parameter, this notification is generated either at a predefined regular interval determined by a user configurable timer. The MIM user (node applications) receives this event from the link layer. The MIM user (node applications) then passes this notification to the SDN controller that has subscribed for this notification.

Table 7-5 – Payload optional information of 'Link Get Parameters' message

Optional information of request message	Optional information of response message
Link ID	Link ID Link configuration list

e) Signalling requirements for link actions

Link_Actions messages are used by the SDN controller to control the behaviour of the links in the SDN switch and to request an action on a link-layer connection to enable optimal handling of link-layer resources for the purpose of handovers. As shown in Table 7-6, the Link_Actions request message contains an action list on link-layer connection that requests shutdown, remaining active, performing a scan, changing into active mode, handover initiation, handover resource request and remaining in stand-by mode. The SDN controller generates this message upon request from the SDN application (e.g., multi-access management functions) to perform an action on a predefined link-layer connection. Upon receipt of this message, the link-layer technology supporting the current link-layer connections performs the action specified by the action list of Link_Actions message in accordance with the procedures specified by the relevant standards organization.

Table 7-6 – Payload optional information of 'Link Action' message

Optional information of request message	Optional information of response message
Link ID Action list	Link ID Status (action-related information)

f) Signalling requirements for subscription/unsubscription of link event

Link_Event_Subscribe messages are used by the SDN controller to subscribe to one or more events (link SNR threshold, link capacity monitoring, link error rate, etc.) from a specific link in the SDN switch. The response indicates which of the requested events were successfully subscribed to. Events that were not successfully subscribed to will not be delivered to the subscriber.

Table 7-7 – Payload optional information of 'Link Event Subscribe/Unsubscribe' message

Optional information of request message	Optional information of response message
Link ID Event list	Link ID Status (event related information)

Link_Event_Unsubscribe messages are used by the SDN controller to unsubscribe a set of previous subscribed events from a link in the SDN switch. This message is generated by a subscriber such as the SDN controller that is seeking to unsubscribe from an already subscribed set of events.

g) Signalling requirements for link probe

Link_Probe messages are used by the SDN controller to request the SDN switch to probe an associated node. It issues the switch to send a null data frame to the node, reporting when the frame is acknowledged.

Table 7-8 – Payload optional information of 'Link Probe' message

Optional information of request message	Optional information of response message
Link ID	Status (link up/down/going-down information)

h) Signalling requirements for attaching/detaching node

Node_Attached and Node_Detached messages are sent by the SDN switch to notify the SDN controller about the detection of the attachment/detachment of a node.

Table 7-9 – Payload optional information of 'Node Attached/Detached' message

Optional information of Node_Attached message	Optional information of Node_Detached message
Link ID Node address	Link ID Node address

8 High-level signalling protocol procedures of SDN-based access networks with MIM capabilities

This clause describes and illustrates signalling flows to support media independent link resource management and seamless handover in SDN-based access networks with MIM capabilities. By using the messages defined in clause 7, signalling protocol procedures are described for the signalling architecture models of loosely-coupled and tightly-coupled integrations of SDN and MIM control frameworks. Two integration models have the same signalling procedure between an MIMF-enabled SDN switch and an MIMF-enabled SDN controller to support link resource management and seamless handover. However, in the loosely-coupled approach an internal signalling procedure is needed between SDN and MIM functions in the SDN switch and SDN controller. On the other hand, in the tightly-coupled approach, MIM information is assumed to be exchanged between mobile node and SDN switch by using any of available protocols.

a) Signalling protocol procedure for resource management

Resource management in the loosely-coupled approach is classified into the following three steps:

1) process of connecting a mobile node and a neighbour SDN switch;
2) process of receiving a probe message from an MIMF-enabled SDN controller after connecting process;
3) process of requesting the setting value of the mobile node from an SDN controller with MIM.

Figure 8-1 illustrates the signalling procedure for resource management in the loosely-coupled approach. A mobile node connects to a nearby SDN switch using MIM information. This information is encapsulated in an SDN message at the connected SDN switch and transmitted to the MIMF-enabled SDN controller. The MIMF-enabled SDN controller 'decapsulates' the received message, confirms the content of the message, and registers the mobile node in the management application.

After the connection process is completed, probe message can be periodically requested from MIMF-enabled SDN controller through SDN switch to confirm whether mobile node is connected. Then, the MIMF-enabled SDN controller can send the parameter request messages that request the setting value or the status value of a mobile node. The SDN switch that receives the request message forwards it to the mobile node, and the mobile node sends a response message to the MIMF-enabled SDN controller through the SDN switch.

Figure 8-2 illustrates the signalling procedure for resource management in the tightly-coupled approach. The procedure is the same as for the loosely-coupled approach, but the message formats are different between the two approaches. In the loosely-coupled approach a message is exchanged between an SDN switch and an MIMF-enabled SDN controller by encapsulating MIM messages into the southbound protocol (e.g., OpenFlow). But in the tightly-coupled approach, it is possible to extend the southbound protocol for the MIM message or to add an SDN message type for MIM. Also, the MIM information exchanged between an SDN switch and a mobile node is the same as in the loosely-coupled approach, but there may be a difference in the protocol used for exchanging the MIM information. In this tightly-coupled approach, it is assumed that MIM information sent from a mobile node is transmitted to REST (representational state transfer), which is one kind of application protocol.

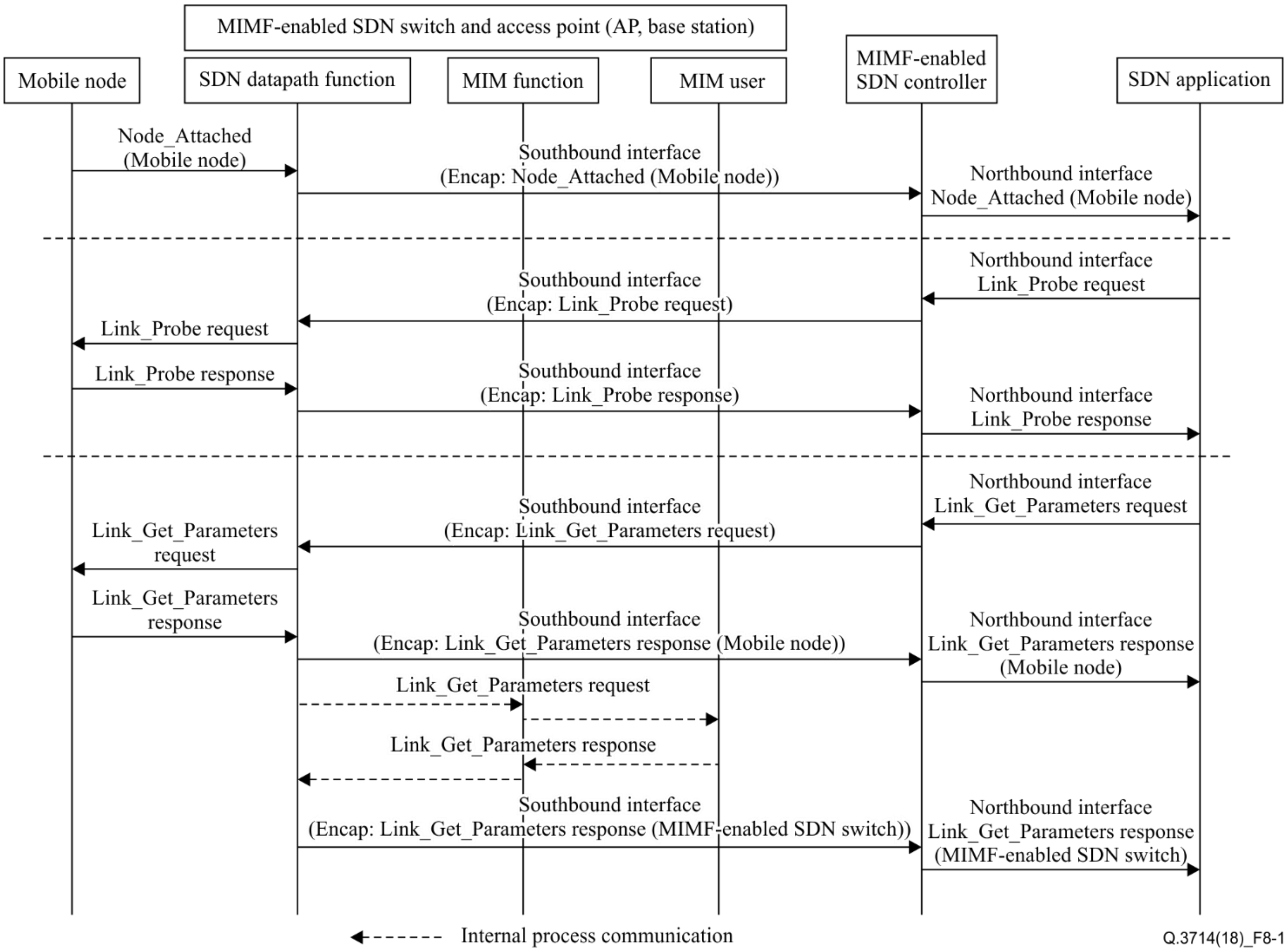

Figure 8-1 – Procedures for resource management (loosely-coupled approach)

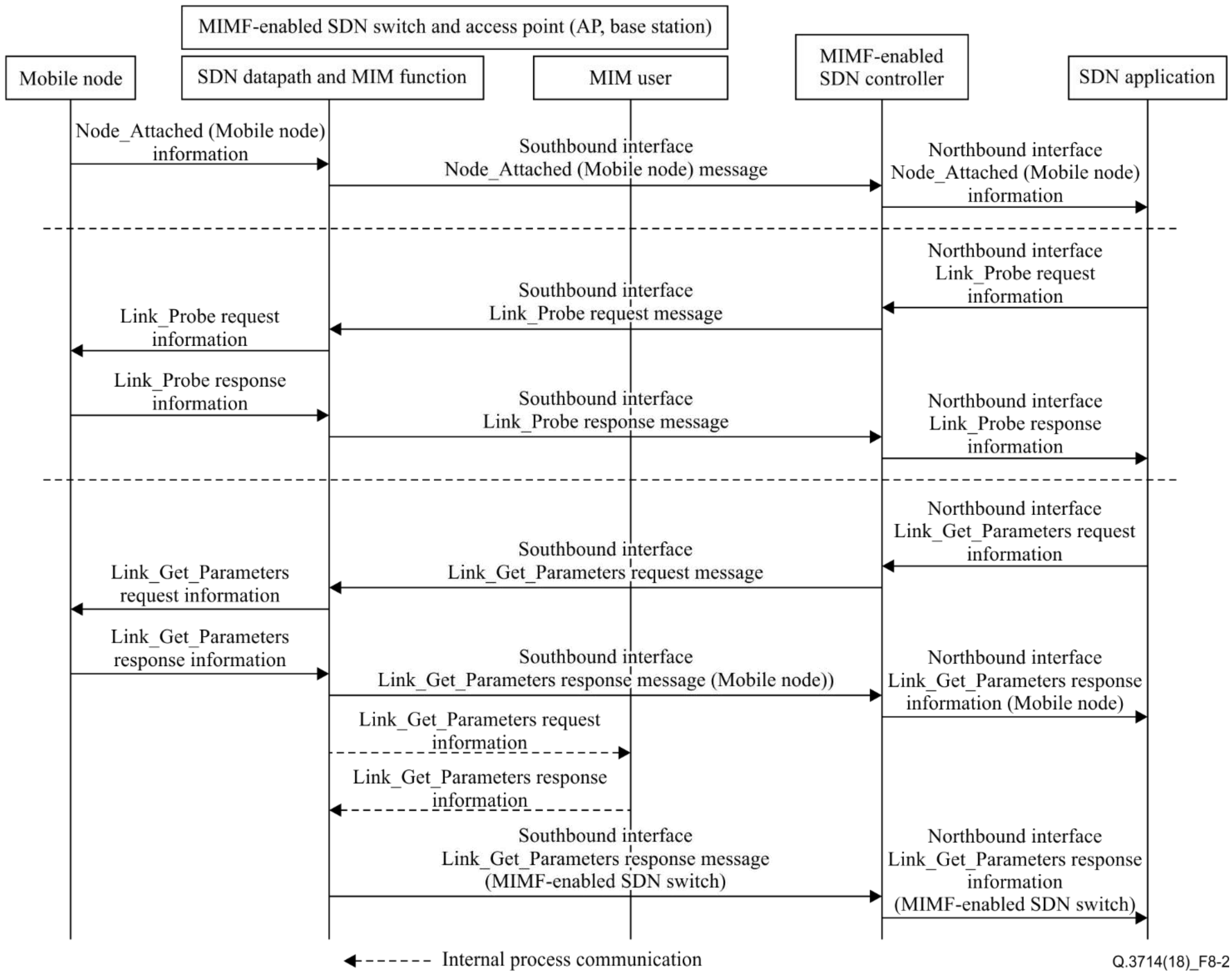

Figure 8-2 – Procedures for resource management (tightly-coupled approach)

b) Signalling protocol procedure for seamless handover

Seamless handover in both the loosely-coupled and tightly-coupled approaches is classified into the following three steps:

1) resource availability check;

2) resource preparation;

3) seamless handover execution.

Figures 8-3 to 8-5 show the signalling procedure for seamless handover in the loosely-coupled approach. The following procedure describes seamless handover in the network environment with the same type (MAC, etc.) of network devices. A mobile node checks the resource of a nearby SDN switch. In the SDN switch to which the mobile node is connected, it is difficult to confirm the resource of the nearby SDN switch directly. Therefore, a related MIM message is transmitted to an MIMF-enabled SDN controller, and the MIMF-enabled SDN controller transmits an MIM message to the nearby SDN switch for checking resources. The mobile node receives resource information of neighbouring SDN switches, chooses a candidate SDN switch and requests resource preparation. When the resource preparation is completed, a new connection is completed with the candidate SDN switch, and the old connection is released from the serving SDN switch.

Figures 8-6 to 8-8 show the signalling procedure for seamless handover in the tightly-coupled approach. The procedure is the same as that of the loosely-coupled approach, but the format of messages exchanged between the SDN switch and SDN controller is different from that of the loosely-coupled approach.

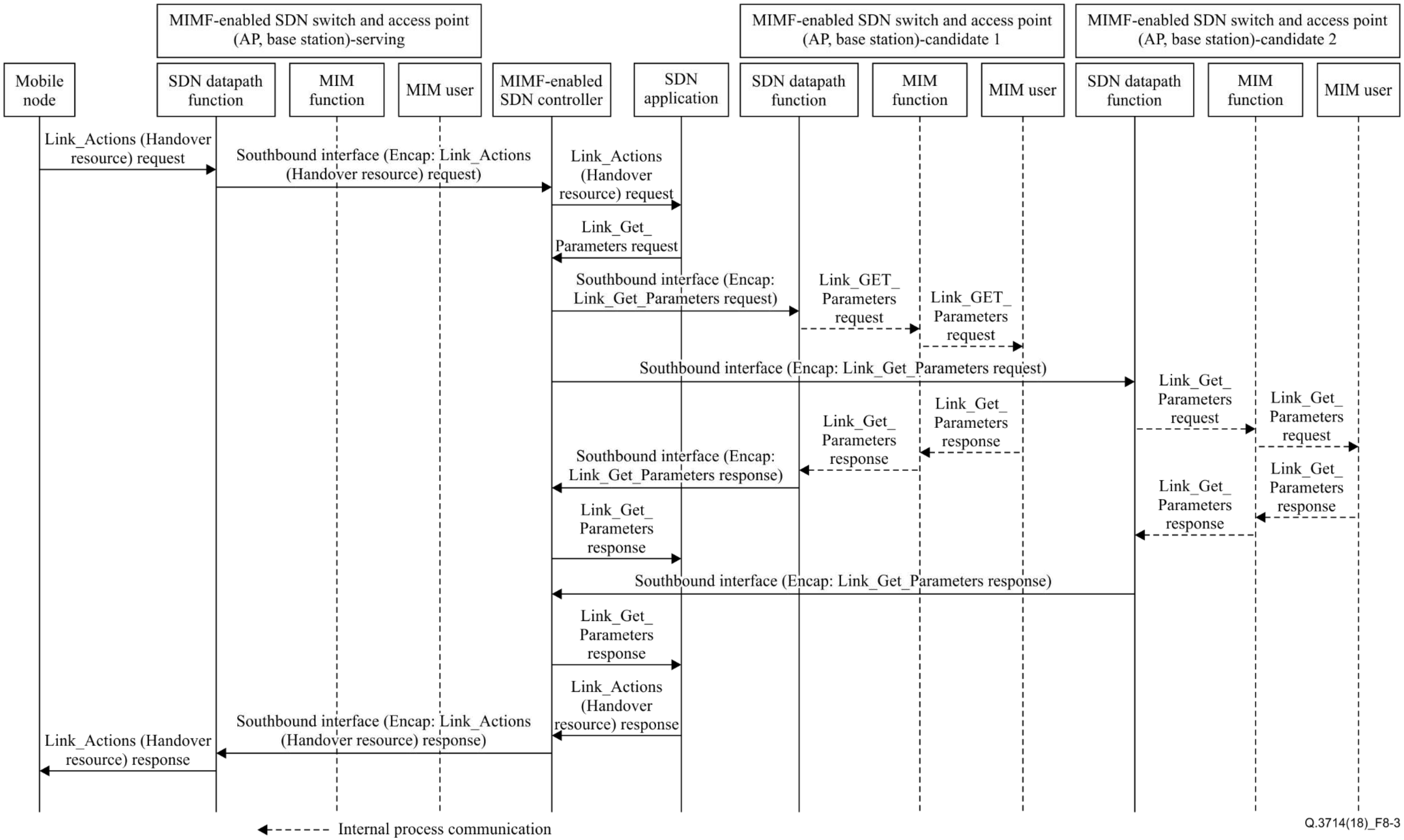

Figure 8-3 – Procedures for seamless handover (loosely-coupled approach) – (a) Resource availability check

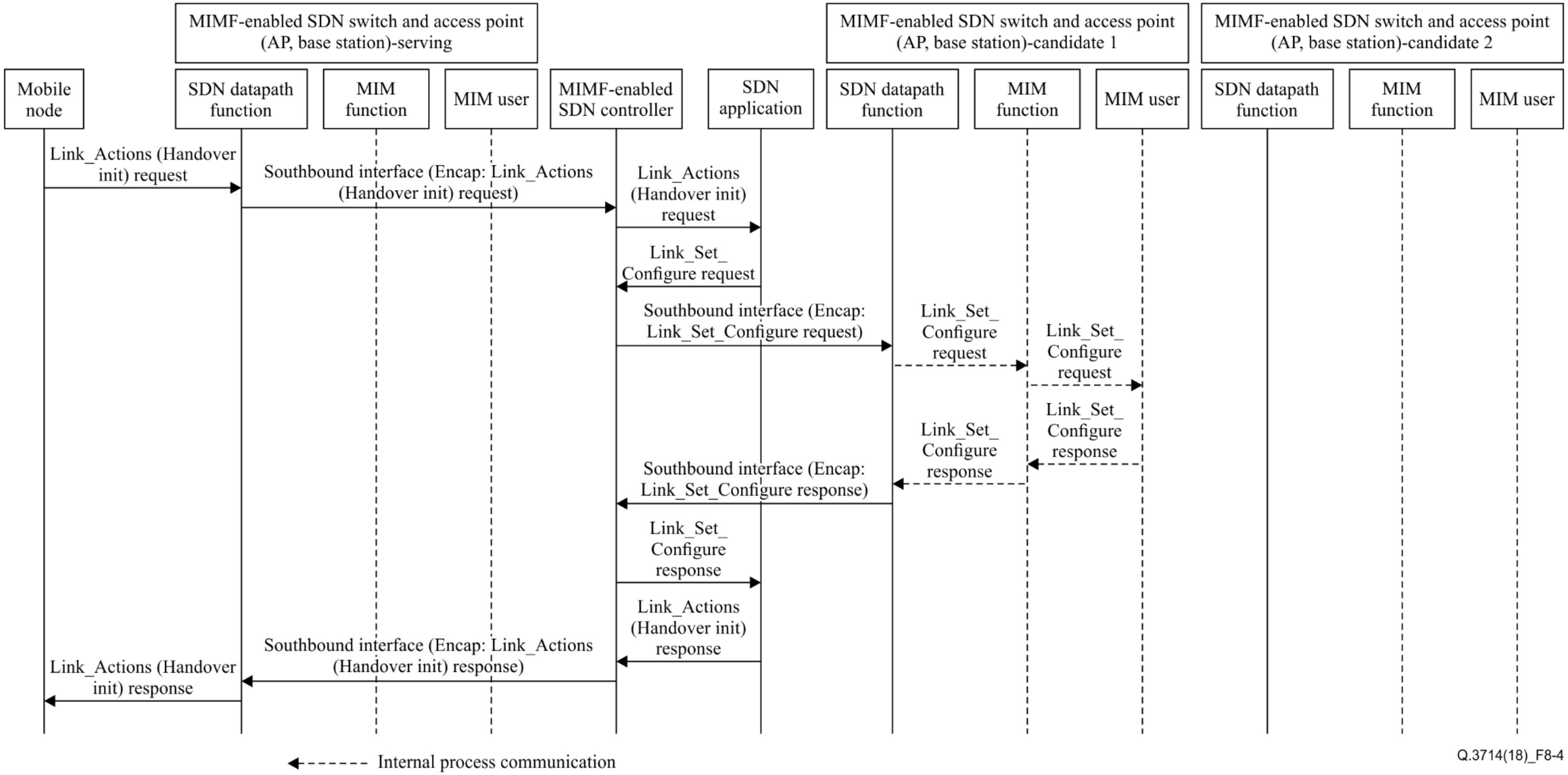

Figure 8-4 – Procedures for seamless handover (loosely-coupled approach) – (b) Resource preparation

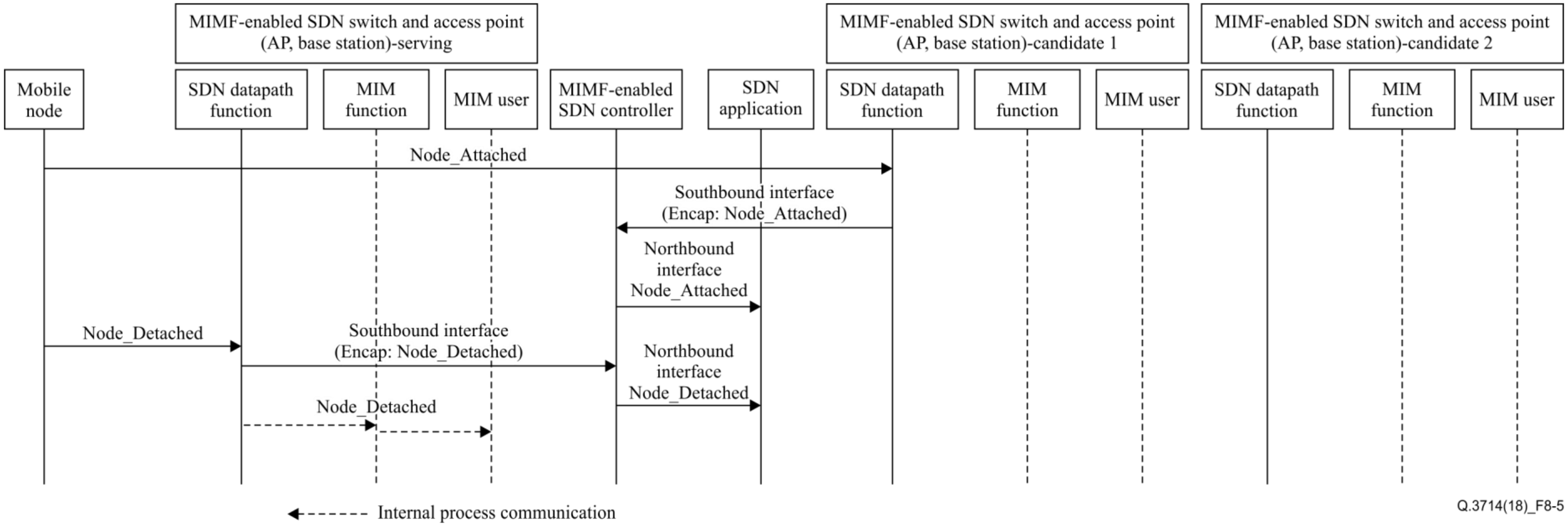

Figure 8-5 – Procedures for seamless handover (loosely-coupled approach) – (c) Seamless handover execution

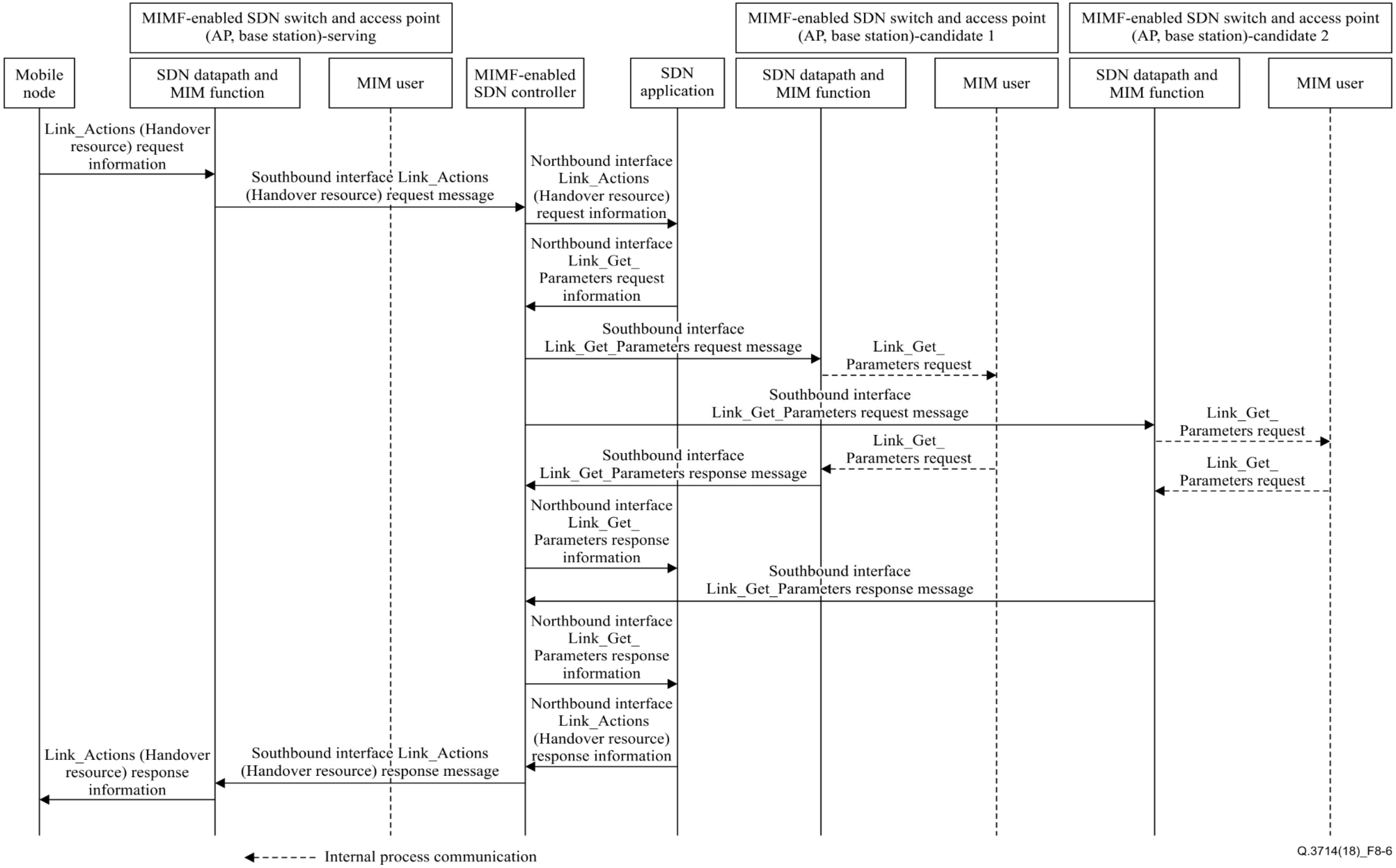

Figure 8-6 – Procedures for seamless handover (tightly-coupled approach) – (a) Resource availability check

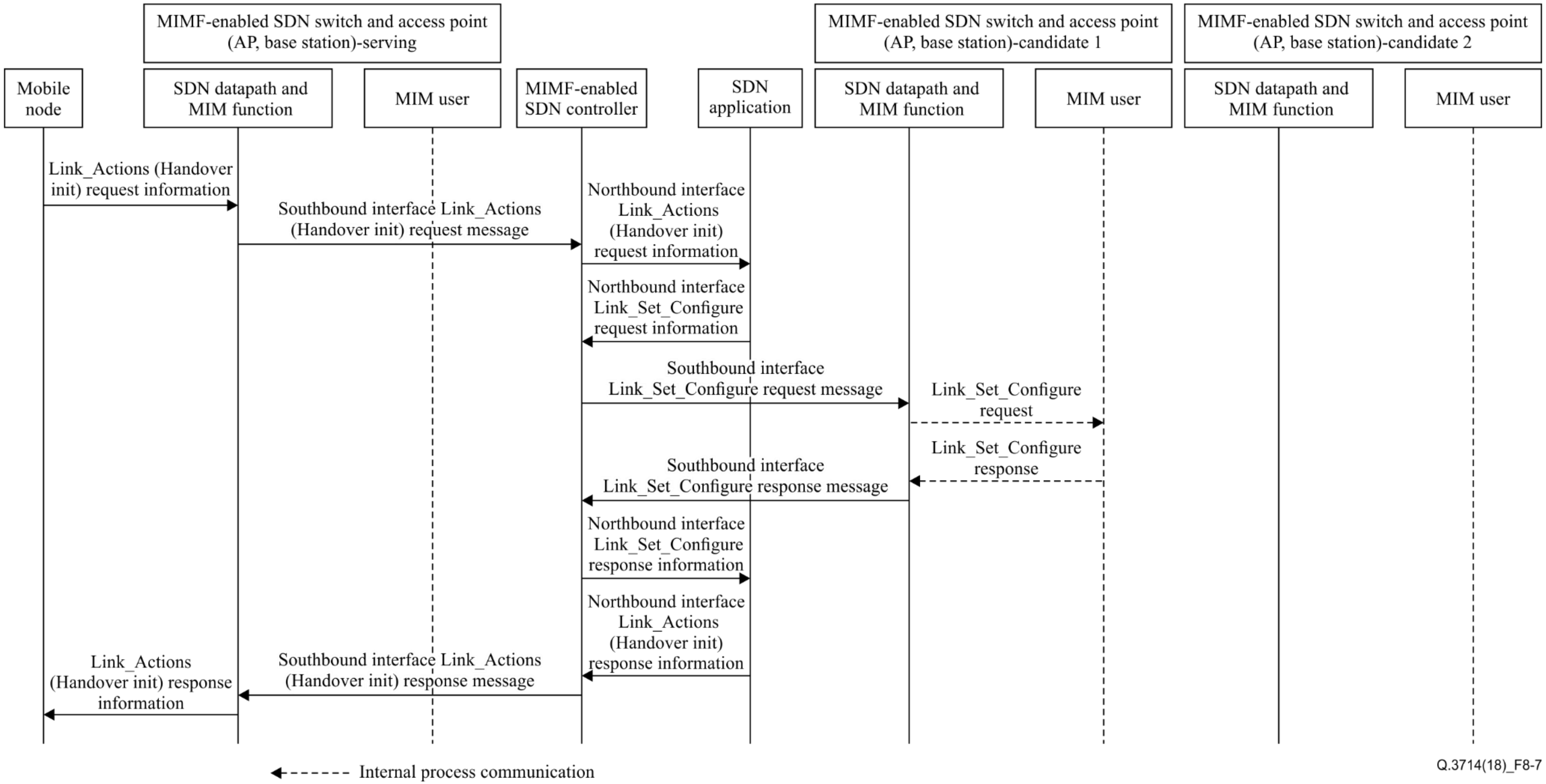

Figure 8-7 – Procedures for seamless handover (tightly-coupled approach) – (b) Resource preparation

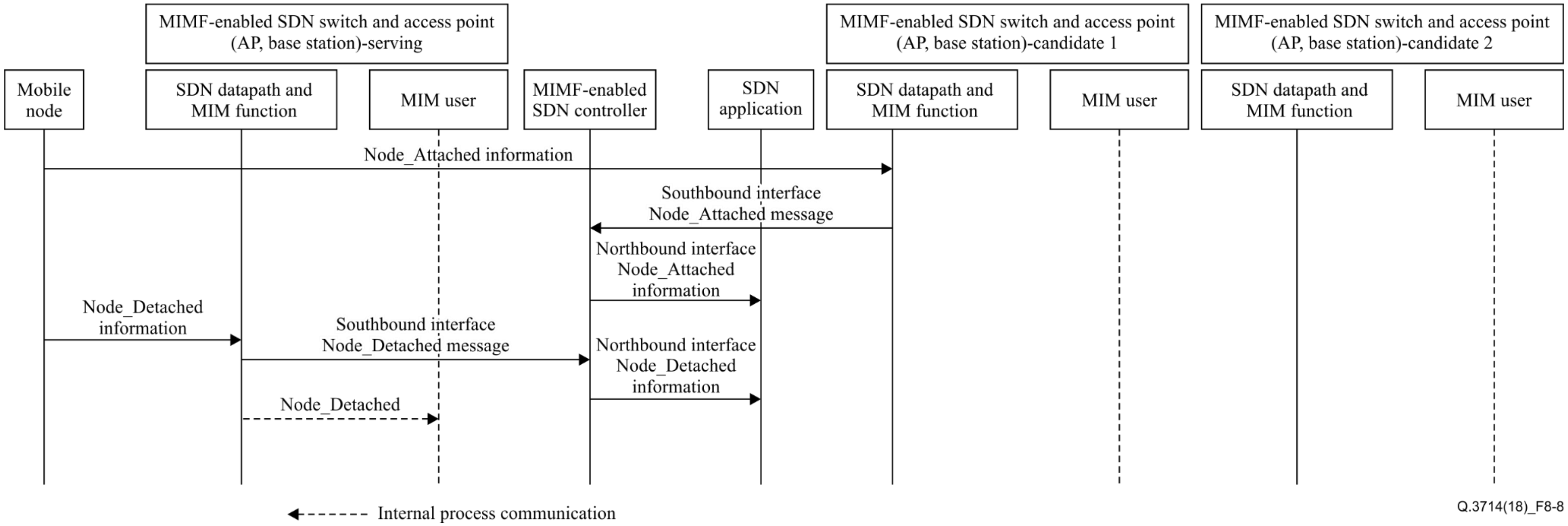

Figure 8-8 – Procedures for seamless handover (tightly-coupled approach) – (c) Seamless handover execution

Appendix I

Related works

(This appendix does not form an integral part of this Recommendation.)

The Open Networking Foundation (ONF) listed the challenges and benefits of SDN for mobile and wireless networks [b-ONF Tech. Rep.]. [b-ITU-T Q.Supp. 67] provides the framework of signalling for SDN in ITU-T Study Group 11. This supplement provides the signalling requirements and architecture for SDN, as well as the interfaces and signalling protocol procedures. These requirements and the signalling information elements identified will enable the development of a signalling protocol(s) capable of supporting traffic flows.

[b-ITU-T Q.Supp. 67] describes a software-defined mobile network (SDMN) that is the future wireless mobile network integration of various radio access networks connected through an SDN controller. It describes that SDMN is an approach to the design of wireless mobile networks where the centralized SDN controller enables a mobility management of the core network, and a traffic path and resource management of radio access networks (RANs). In the SDMNs, most of the mobile applications are based on radio-specific interaction functions. The interaction deals with L1/L2 functions, specifically the interaction among heterogeneous RAN technologies. This interaction also introduces new challenges in radio resource allocation or seamless handover. The SDN paradigm is used to control RANs since the centralized controller can simplify radio resource management and lower mobility management costs.

The IEEE 802.21-2017 (or media independent services (MISs) framework) standard [b-IEEE 802.21] defines extensible media access independent mechanisms (i.e., function and protocol) that enables the optimization of services including a handover service when performed between heterogeneous networks. [b-IEEE 802.21.1] defines several use cases and services, namely, handover between heterogeneous networks, home energy management system, software-defined radio access networks (SDRANs), radio resource management, and device-to-device communication services that need to be implemented in conjunction with the MIS framework as specified in [b-IEEE 802.21] .

[b-IEEE 802.21] defines a set of media independent commands, events and information elements, made available by a media independent service function (MISF) residing in supporting nodes, which, through the usage of service access points (SAPs) interfacing, abstracts access to information and control procedures of the link layers, independently of their technology (e.g., WLAN, WiMAX, 3GPP, etc.). These mechanisms are used by controlling entities (e.g., high-level mobility management entities) to optimize handover procedures, optimizing connectivity in wireless mobility-supporting scenarios. IEEE 802.21 is referred as a potential enabler to query link information and to trigger handovers in SDN-based wireless networks.

The signalling framework of [b-IEEE 802.21] can be a common platform to support mobility management in heterogeneous networks. The signalling framework supports the seamless handover in heterogeneous RANs. Some primitives and messages help the mobile node (MN) to monitor link status (e.g., signal strength and data rate), and some primitives and messages help the MN to control its link layers (physical layer and data link layer) for seamless handover in heterogeneous RANs. Some primitives and messages can be used to transfer network configuration information for handover and mobility management via a clearly separated control plane in SDMNs, and thus they can be used to provide seamless network configuration for resource allocations while the MN is moving across RANs. Thus, the signalling framework is appropriate for radio resource allocation and mobility management in SDN-based access networks that use various heterogeneous RANs by a clear separation of the control and data plane.

The SDRANs use case of [b-IEEE 802.21] describes how the MIS framework is used to support the seamless handover in the SDRAN environment that includes both fronthaul and backhaul networks.

The MIS framework enables operators to provide link-layer intelligence, allocate radio resources, and optimize handovers when a mobile device is switching between heterogeneous networks that are managed by the SDN controller. However, this use case only illustrates an example of the decoupled interworking framework of SDN and MIM control that is described in clause 6.2 of this Recommendation. This Recommendation describes not only the decoupled interworking but also the loosely-coupled and tightly-coupled integrations of SDN and MIM control frameworks to support signalling scenarios related with radio resource allocation and seamless handover.

Appendix II

Use cases

(This appendix does not form an integral part of this Recommendation.)

This appendix describes use cases of this Recommendation, which are seamless vertical handover, link aggregation, and coping with interference in wireless networks.

II.1 Use case of seamless vertical handover

This use case describes how to support seamless handover using an MIMF-enabled SDN switch and MIMF-enabled SDN controller in a heterogeneous network. In this use case, the MIMF-enabled SDN switch is collecting information (status and configuration) of wireless resources from the mobile node, and transmitting it to the MIMF-enabled SDN controller. The MIMF-enabled SDN controller makes decisions based on the collected information. For this purpose, the MIMF-enabled SDN controller periodically monitors change of the radio signal that is reported as an event by mobile node or MIMF-enabled SDN switch.

The process of seamless vertical handover is divided into three parts: preparation, decision and execution. As illustrated in Figure II.1, the MIMF-enabled SDN controller performs management of the various resources of the wireless network during the handover process in the SDN with MIM.

1) Handover preparation: checks for decrease in signal strength or link quality, and neighbouring networks are discovered and information is exchanged;
2) handover decision: best network is selected from different available networks using a decision algorithm;
3) handover execution: connection transfer, handover signalling and packet reception.

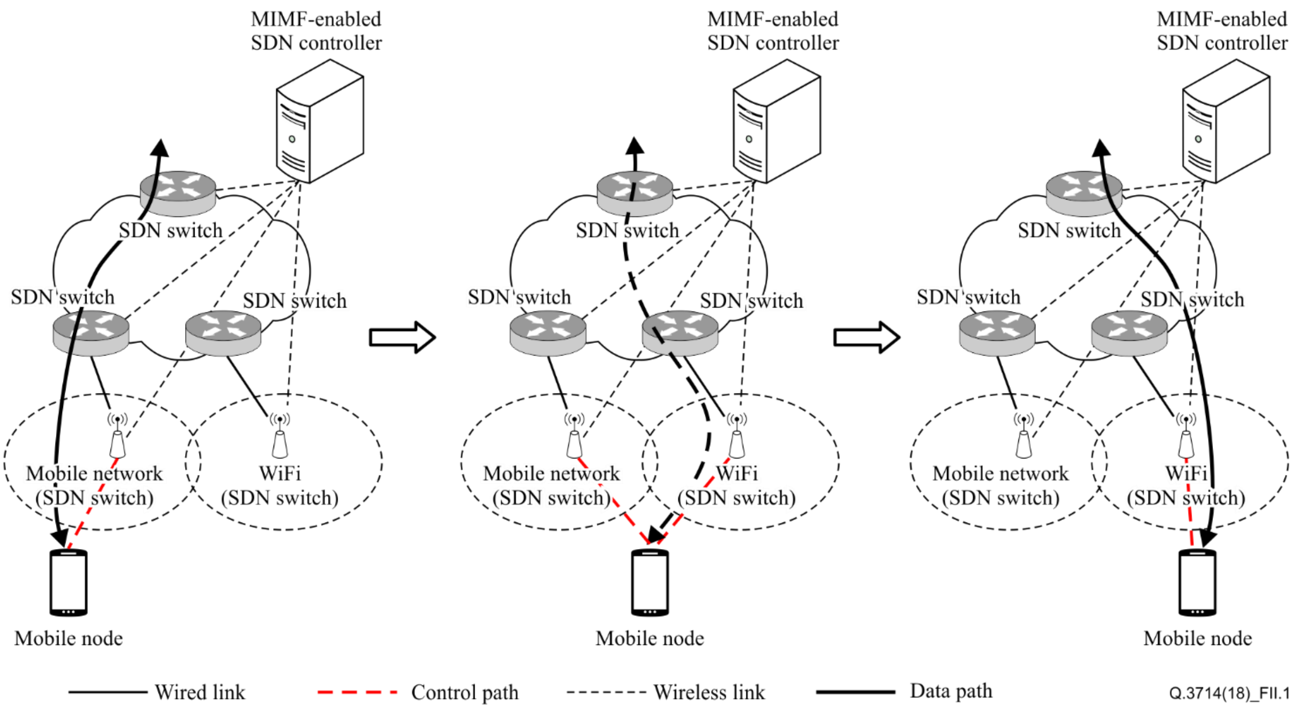

Figure II.1 – Illustration of seamless vertical handover process

II.2 Use case of link aggregation

Aggregation of multiple physical links into a single logical link is to provide bandwidth extension, QoS guarantee and multipath support. For physical and link layer aggregations, network interface card (NIC)-based or virtual LAN (VLAN)-based bonding is used in wired access networks, and channel bonding is used in wireless access networks. For transport layer aggregation, multipath TCP (MTCP) is used in wired and wireless networks.

In this use case the MIMF-enabled SDN controller monitors the status of ports and links in the MIMF-enabled SDN switch, and performs dynamic link control based on real-time monitoring. This approach can reduce packet loss and/or reordering during link aggregation since it is possible to analyse the transport header in the SDN switch.

This is an example of wireless link aggregation by an MIMF-enabled SDN controller. Link aggregation requires wireless resource monitoring and routing. In this use case we proceed through these settings by the MIMF-enabled SDN controller as shown in Figure II.2. The advantage of this is that it can be applied quickly in a dynamic environment.

1) SDN switch, Wi-Fi and mobile networks are controlled by an MIMF-enabled SDN controller;
2) request large amounts of data from a mobile node to the server;
3) the mobile node is connected to Wi-Fi and a mobile network;
4) the transmission of data from the server to the mobile node through Wi-Fi and a mobile network. It is controlled by the MIMF-enabled SDN controller.

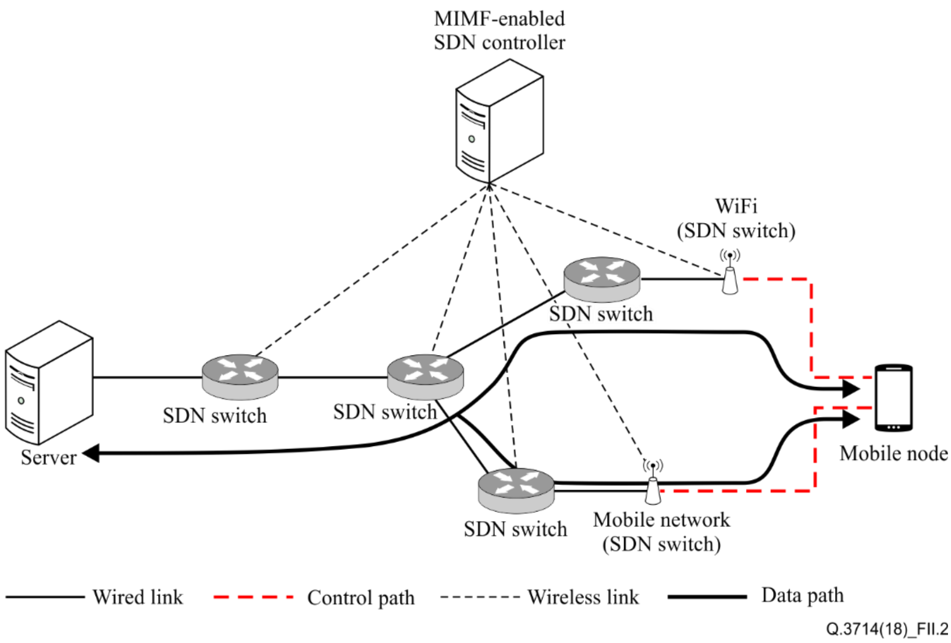

Figure II.2 – Illustration of link aggregation

II.3 Use case of coping with interference in wireless network

Recently the number of installed APs and base stations has been increased due to a drastic increase in mobile data traffic. Hence, the interference between APs or between AP and base station has resulted in the deterioration of link quality and network performance. This use case uses an MIMF-based SDN controller to resolve this issue. The MIMF-enabled SDN controller gathers wired and wireless information, and allocates frequencies and channels to the AP and base station based on this information. It can select an AP or a base station for a mobile node based on the mobile node profile if there are two or more candidate APs and base stations for serving the mobile node.

Figure II.3 shows a case where a collision occurs between wireless network resources. An MIMF-enabled SDN controller is used to monitor radio resources. When such an interference occurs the MIMF-enabled SDN controller checks the node profile to provide the network service only to the more suitable network, or to select the network service considering the network environment.

1) Mobile node A receives data through a mobile network, and mobile nodes B and C receive data through Wi-Fi;
2) mobile node A is moving to a Wi-Fi service area;
3) when mobile node A enters the Wi-Fi service area, inter-RAT interference occurs;
4) when a new mobile network (small cell) is installed near mobile node B, the mobile node B interferes with the intra-RAT. When using the same frequency in a mobile network (small cell) and Wi-Fi, channel interference occurs.

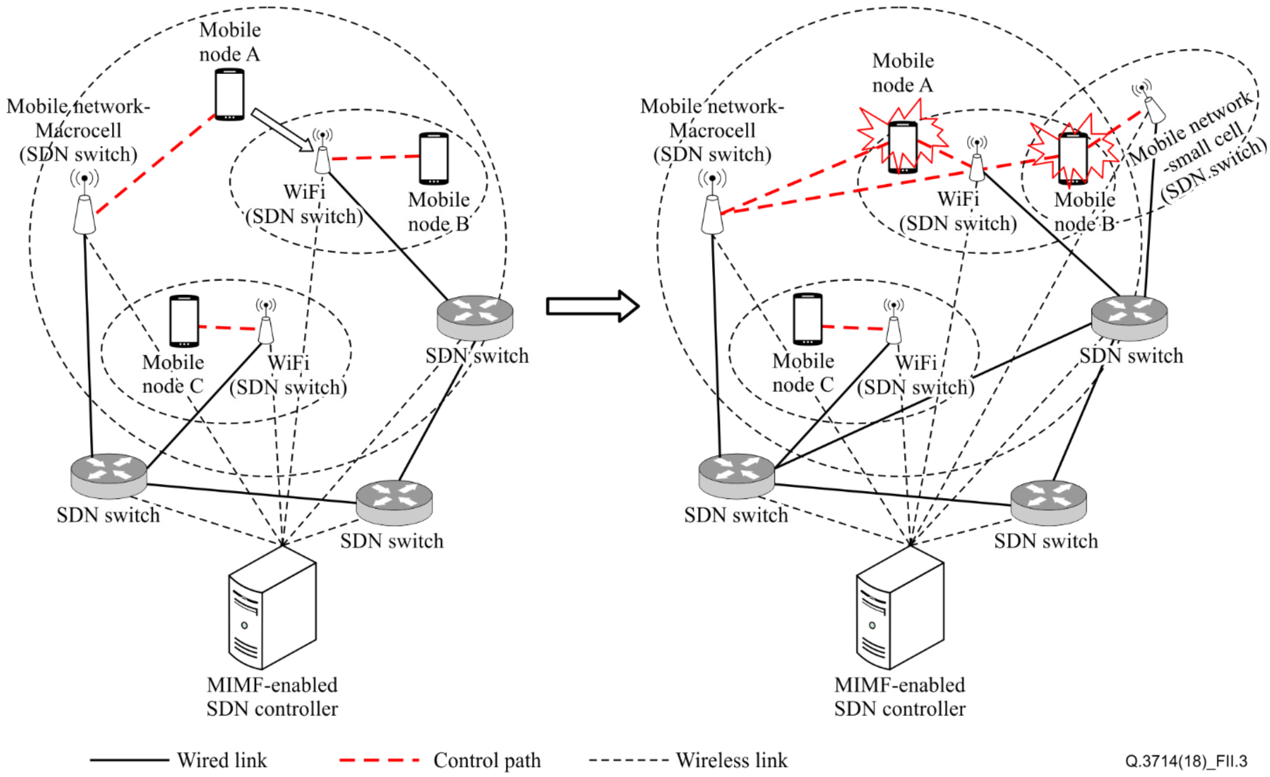

Figure II.3 – Illustration of interference in a wireless network

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