International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

Y.4417

(06/2018)

SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

Internet of things and smart cities and communities – Frameworks, architectures and protocols

---

Framework of self-organization networking in Internet of things environments

Recommendation ITU-T Y.4417

ITU-T

ITU-T Y-SERIES RECOMMENDATIONS

GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

GLOBAL INFORMATION INFRASTRUCTURE	
General	Y.100–Y.199
Services, applications and middleware	Y.200–Y.299
Network aspects	Y.300–Y.399
Interfaces and protocols	Y.400–Y.499
Numbering, addressing and naming	Y.500–Y.599
Operation, administration and maintenance	Y.600–Y.699
Security	Y.700–Y.799
Performances	Y.800–Y.899
INTERNET PROTOCOL ASPECTS	
General	Y.1000–Y.1099
Services and applications	Y.1100–Y.1199
Architecture, access, network capabilities and resource management	Y.1200–Y.1299
Transport	Y.1300–Y.1399
Interworking	Y.1400–Y.1499
Quality of service and network performance	Y.1500–Y.1599
Signalling	Y.1600–Y.1699
Operation, administration and maintenance	Y.1700–Y.1799
Charging	Y.1800–Y.1899
IPTV over NGN	Y.1900–Y.1999
NEXT GENERATION NETWORKS	
Frameworks and functional architecture models	Y.2000–Y.2099
Quality of Service and performance	Y.2100–Y.2199
Service aspects: Service capabilities and service architecture	Y.2200–Y.2249
Service aspects: Interoperability of services and networks in NGN	Y.2250–Y.2299
Enhancements to NGN	Y.2300–Y.2399
Network management	Y.2400–Y.2499
Network control architectures and protocols	Y.2500–Y.2599
Packet-based Networks	Y.2600–Y.2699
Security	Y.2700–Y.2799
Generalized mobility	Y.2800–Y.2899
Carrier grade open environment	Y.2900–Y.2999
FUTURE NETWORKS	Y.3000–Y.3499
CLOUD COMPUTING	Y.3500–Y.3999
INTERNET OF THINGS AND SMART CITIES AND COMMUNITIES	
General	Y.4000–Y.4049
Definitions and terminologies	Y.4050–Y.4099
Requirements and use cases	Y.4100–Y.4249
Infrastructure, connectivity and networks	Y.4250–Y.4399
Frameworks, architectures and protocols	**Y.4400–Y.4549**
Services, applications, computation and data processing	Y.4550–Y.4699
Management, control and performance	Y.4700–Y.4799
Identification and security	Y.4800–Y.4899
Evaluation and assessment	Y.4900–Y.4999

For further details, please refer to the list of ITU-T Recommendations.

Recommendation ITU-T Y.4417

Framework of self-organization networking in Internet of things environments

Summary

Self-organization networking is where autonomous networking is established by individual devices, and where the device effectively interacts with its peers and performs self-control. In IoT environments, self-organization networking is required when the heterogeneous devices belong to infrastructure-unsupported IoT area networks. Recommendation ITU-T Y.4417 specifies a framework of self-organization networking for IoT in a particular area of telecommunications. The Recommendation presents the concepts, characteristics, architecture, requirements and functionalities of self-organization networking.

History

Edition	Recommendation	Approval	Study Group	Unique ID[*]
1.0	ITU-T Y.4417	2018-06-29	20	11.1002/1000/13639

Keywords

Internet of things (IoT), self-organization networking.

---

[*] To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

Table of Contents

Recommendation ITU-T Y.4417

Framework of self-organization networking in Internet of things environments

1 Scope

The scope of this Recommendation includes:

- concepts of self-organization networking in Internet of things (IoT) environments
- characteristics of self-organization networking in IoT environments
- requirements for self-organization networking in IoT
- functional architecture for self-organization networking in IoT
- functionalities of self-organization networking for IoT.

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.4000]	Recommendation ITU-T Y.4000/Y.2060 (2012), *Overview of the Internet of things*.
[ITU-T Y.4100]	Recommendation ITU-T Y.4100/Y.2066 (2014), *Common requirements of the Internet of things*.
[ITU-T Y.4101]	Recommendation ITU-T Y.4101/Y.2067 (2017), *Common requirements and capabilities of a gateway for Internet of things applications*.
[ITU-T Y.4407]	Recommendation ITU-T Y.4407/Y.2281 (2011), *Framework of networked vehicle services and applications using NGN*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 device [ITU-T Y.4000]: With regard to the Internet of things, this is a piece of equipment with the mandatory capabilities of communication and the optional capabilities of sensing, actuation, data capture, data storage and data processing.

3.1.2 infrastructure [ITU-T Y.4407]: The basic facilities and systems comprised of network nodes (i.e., switches and/or routers) and the means to connect them (i.e., wired (cable or fibre) or wireless) for the purpose of communication between two end-points.

3.1.3 Internet of things [ITU-T Y.4000]: A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.

NOTE 1 – Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, whilst ensuring that security and privacy requirements are fulfilled.

NOTE 2 – From a broader perspective, the IoT can be perceived as a vision with technological and societal implications.

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 self-organization networking (SON): Autonomous networking established by individual devices, where the device can effectively interact with its peers and perform self-control for network organization and for joining networks according to its own status, own services and dynamic network circumstances in a decentralized infrastructure or an "infrastructure-less" network.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ANIMA	Autonomic Networking Integrated Model and Approach
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name System
DSN	Distributed Service Networking
GANA	Generic Autonomic Network Architecture
IBSS	Independent Basic Service Set
IoT	Internet of Things
IP	Internet Protocol
IPv6	Internet Protocol version 6
MANET	Mobile Ad-hoc Networks
NGSON	Next Generation Service Overlay Networks
P2P	Peer-to-Peer
QoS	Quality of Service
SON	Self-Organization Networking
TCP	Transmission Control Protocol
WLAN	Wireless Local Area Network
WPAN	Wireless Personal Area Network

5 Conventions

None.

6 Concepts of self-organization networking in IoT environments

Network configuration and conditions (e.g., network deployment, network size, the number of network devices, connectivity, multi-hop communication, traffic pattern, security level, mobility and quality of service (QoS)) in IoT environments can be different from those in conventional networks. For example, an infrastructure-unsupported IoT area network is independent on pre-existing infrastructure networks.

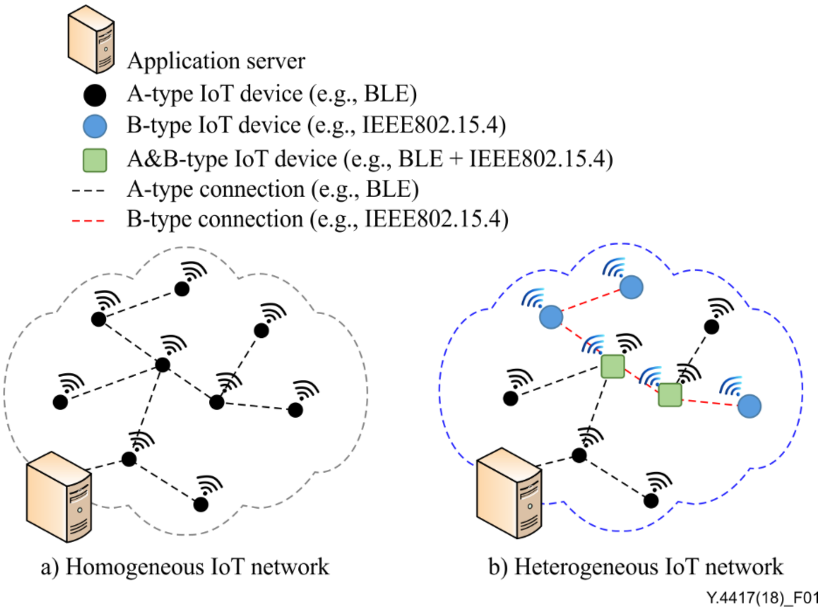


Figure 1 – Infrastructure-unsupported IoT area networks

Figure 1 depicts two cases of infrastructure-unsupported IoT area networks. In infrastructure-unsupported IoT area networks, IoT devices themselves perform various operations such as neighbour node discovery and routing for network configuration and communication services without relying on infrastructure entities. For example, IoT devices in infrastructure-unsupported IoT area networks can be provided for peer-to-peer or server-client connectivity as shown in Figure 1. Self-organization networking (SON) in IoT refers to the communication process, including network protocols, among heterogeneous networked devices. The existing process for conventional networks does not fully support or consider the characteristics of heterogeneous networked devices in infrastructure-unsupported IoT area networks; therefore, SON for IoT is required. The main scope of this Recommendation is SON in infrastructure-unsupported IoT area networks.

7 Characteristics of self-organization networking

From a networking point of view in IoT environments, anything can be interconnected with the global information and communication infrastructure and the devices based on different hardware platforms and networks. The state of the IoT devices can change dynamically (e.g., sleeping, moving, connected and/or disconnected and so on).

Autonomic networking (including self-management, self-configuring, self-healing, self-optimizing and self-protecting techniques and/or mechanisms) needs to be supported in the networking functions of IoT in order to adapt to different application domains and communication environments. In addition, manageability is required in IoT in order to ensure normal network operations. IoT applications usually work automatically without the participation of people, but their whole operation process should be managed by the relevant parties [ITU-T Y.4000].

In order to realize connectivity between things in IoT, connectivity capabilities are also required to be independent of specific application domains. Integration of heterogeneous communication technologies and end-to-end intelligence are required for consideration, in particular with regard to the "intelligence of communications" and the "intelligence of services" [ITU-T Y.4100].

The main purpose of the existing SON is self-management of the network, including self-configuration, self-optimization, self-healing and self-protection. These are to operate and optimize the network without depending on human decisions and a centralized network management system. Whereas in IoT environments, the main purpose of SON is to configure and optimize the network topology for IoT service support. Thus, SON for IoT focuses on self-configuration for network topology, self-device discovery and self-optimization, considering dynamic network circumstances in infrastructure-unsupported IoT area networks.

IoT devices have various capabilities, such as processing, memory, battery power, mobility, bit rates, transmission ranges and so on. In addition, the devices can have different radio access technologies. Characteristics of these resources can influence the performance of SON. For example, if it has been decided that the SON functionalities are for energy-efficient networking, the battery power of the IoT device can be one of the most important considerations.

NOTE – Details of SON functional architectures and functionalities are described in clauses 9 and 10.

8 Requirements for self-organization networking

8.1 Support for heterogeneous IoT networks

Devices in IoT heterogeneous networks are composed of diverse capabilities and access technologies. The SON for IoT is required to be adhered to the characteristics of heterogeneous IoT devices.

8.2 Decentralization of self-organization networking

SON functions are required to be distributed to IoT devices according to IoT services. IoT devices can have multiple roles for different services simultaneously. In case that an IoT device has multiple roles, the roles can be changed according to IoT service requirements and conditions. Therefore, the SON functions cannot be centralized to static IoT devices for service management.

NOTE – SON functions include network functions and coordination functions with optimization polices as described in clauses 9 and 10.

8.3 Support for different networking performance levels

SON is required to support different performance levels of distributed functions for various IoT services. For example, such a performance would be based on energy-centric IoT services, process (or time)-centric IoT services, and so on. The various optimization options give different results of networking performance of IoT services.

8.4 Self-configuration and self-management for networking

It is required to support self-configuration and self-management for networking. Self-configuration includes all kinds of procedures to initiate networking, such as identification, neighbour and route discovery, and so on. Furthermore, self-management includes data routing, congestion control and so on after network initiation.

8.5 Support for network robustness

SON is required to support recovery for network failures by itself. When networking failures occur, neighbouring IoT devices should detect the failures immediately and discover another device instead of the failed device. When there is a backup device, the backup device recovers the existing configurations.

NOTE – For example, when devices move or run out of power, networking failures, such as failures on routing paths, take place. As soon as devices detect the failures they identify another routing path for network robustness.

9 Functional architecture of self-organization networking

The purpose of SON in IoT is to provide autonomous networking through the cooperation of IoT devices. The overall concept of SON in the IoT environment is depicted in Figure 2.

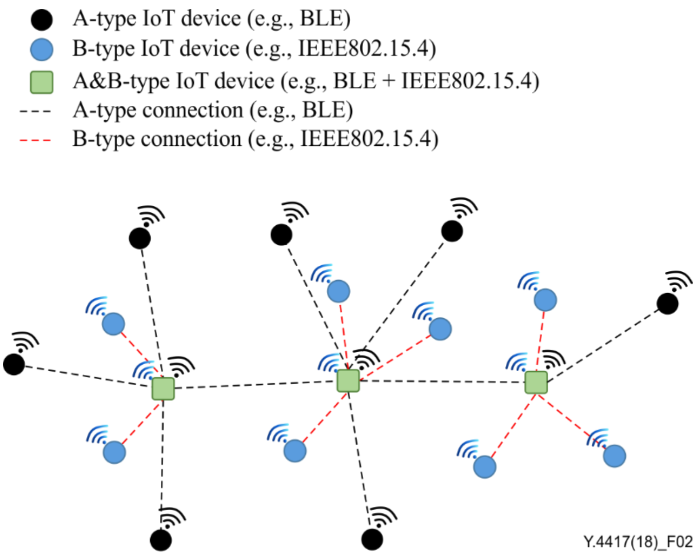


Figure 2 – Overall concept of self-organization networking

The functions of SON are distributed and allocated to each IoT device, and these functions exchange the necessary information for constructing and maintaining a network. For doing this, IoT devices are classified into two groups according to their roles.

– IoT devices (A-type and B-type device in Figure 2).

– IoT coordinators (A and B-type device in Figure 2).

An IoT coordinator is an elected IoT device. IoT coordinators construct routing paths for networking to the other IoT devices, and they perform gateways to neighbouring IoT devices. Therefore, IoT coordinators should have capabilities for connections to various IoT devices. The capability to qualify as an IoT coordinator is determined under performance options. The options are achieved through predefined optimization policies. These policies are determined by service requirements. Figure 3 shows the functionalities for SON which are reflected by the service requirements and characteristics of IoT devices.

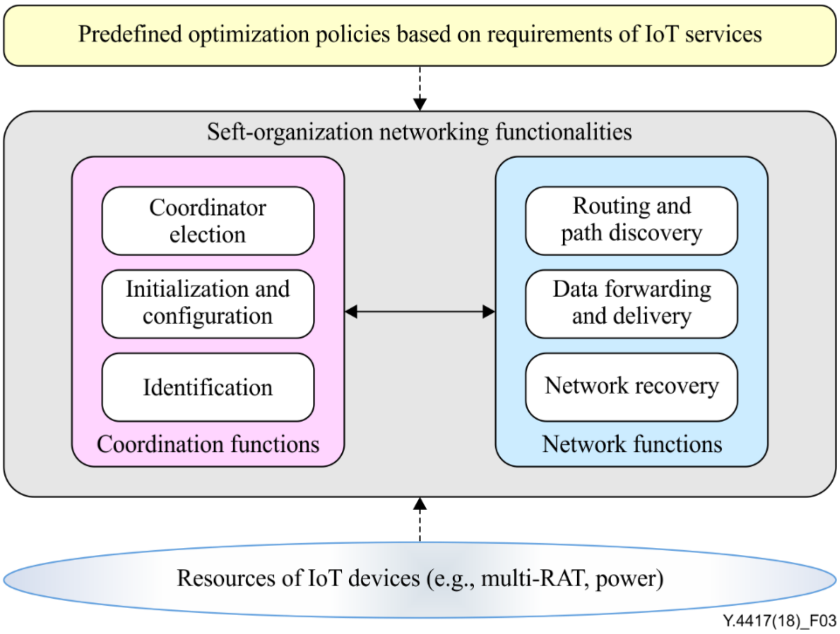


Figure 3 – SON functional architecture

The SON functionalities comprise of two parts:

– ***Coordination functionality***: have roles for building network topologies; for instance, coordinator election, initialization and configurations to build connections between two neighbouring devices, and identification.

– ***Network functionality***: have roles of path discovery, routing, data forwarding and delivery, and network recovery.

The key functionalities of SON are functions for coordination among IoT devices. SON is more effective and dynamic owing to relatively simple configurations based on characteristics of services then conventional networking. After building a self-organization network, network functions are processed; for example, discovering routing paths, forwarding data packets, and recovering network failures.

Furthermore, predefined optimization policies are built in terms of the requirements of specific IoT services and applications, and the two functionalities base their operation on these policies. With the coordination functionality, IoT devices, which have identification, collect resource information from neighbouring IoT devices, such as remaining energy, processing performance, etc. The coordination functions elect coordinators and build initialization and configurations to control network topologies. While network functionality builds routing paths for packet forwarding in terms of the elected coordinators and the policies for optimization. Then data delivery gets started.

The role of optimization policies is to analyse the current status and requirements for its services and decide an optimal policy based on the requirements and constraints. The determination of optimization policies is dependent on the characteristics of the requirements of IoT services. If IoT services require energy-efficient networking, all procedures are focused on energy saving. If IoT services want high performance (e.g., high-speed or big-data processing), SON is built for high-performance. Such policies can vary according to the characteristics of the required IoT services.

10 Functionalities for self-organization networking

10.1 Coordination functionality

The coordination functionality has roles for building network topologies; for instance, coordinator election, connection between two neighbouring devices and topology control for recovery. Therefore, the coordination functionality has three specific functions, such as coordinator election, neighbour connection, and error recovery.

10.1.1 Coordinator election

As shown in Figure 3, SON is started in terms of coordinators. Coordinators have two important roles of managing neighbouring IoT devices and forwarding packets. Therefore, the best qualified IoT devices should become coordinators. The qualification is determined by optimization policies.

Coordinators collect information of neighbouring IoT devices for the management role. This information is exploited to connect neighbouring IoT devices as well as recover errors. After the information is collected, coordinators start to connect all of the neighbouring IoT devices, and star topologies are built in terms of coordinators. The coordinators play a gateway for the neighbouring IoT devices. If one of the coordinators is failed, the election for a brand new coordinator starts, and one of the other best qualified IoT devices become the new coordinator by recovery mechanisms.

10.1.2 Initialization and configurations

All of the IoT devices should belong to one of the coordinators for management. Hence, the IoT devices are connected to one of the coordinators, and start topologies based on the coordinators are built. Theses connections are exploited for data forwarding.

After coordinators are elected, coordinators broadcast advertisement packets. When neighbouring IoT devices receive the advertisement, the IoT devices reply connection request packets to the coordinators. Then connections between IoT devices are built in terms of the elected coordinators.

When an elected coordinator has failed all of the neighbouring IoT devices are disconnected and coordination election (in clause 10.1.1) restarts.

10.1.3 Identification

The conventional identification schemes networking protocols are not always appropriate for IoT devices (especially constrained IoT devices). If so, infrastructure-unsupported network IoT devices can require brand new identification schemes and networking protocols, which are appropriate to optimization policies. The new identification schemes are required to be simple for energy efficiency or high performance.

10.2 Network functionality

Network functionality is to enable data communication with infrastructure-unsupported network IoT devices. Therefore, network functionality for SON in IoT has three specific functions: routing and path discovery, data forwarding and delivery, and network recovery.

10.2.1 Routing and path discovery

When network topologies are built in terms of coordinators, connections between the coordinators should be created. According to optimization policies, connections between coordinators can build different routing paths or different network topologies. After that the routing path is built in terms of the coordinators between a source device and a destination device.

10.2.2 Data forwarding and delivery

Data forwarding can be conducted with three types of traffic patterns including unicasting, multicasting and broadcasting. If IoT services require high performance, networking technologies like multi-homing can be exploited. All of data forwarding is done by coordinators, and IoT devices send/receive data to/from coordinators.

10.2.3 Network recovery

There are two types of network failures. One is failure of coordinators, and the other is failure of IoT devices. If one of the coordinators has failed one of the neighbouring IoT devices becomes a coordinator. Furthermore, if connection between a coordinator and one of the IoT devices has failed, the coordinator tries to reconnect to the IoT device. If the connection is terminated, the coordinator will not manage information of the disconnected IoT device any more.

11 Security considerations

In the infrastructure-unsupported IoT area network, IoT devices themselves perform various operations without relying on infrastructure entities. Also, the functions of SON and most IoT services proceed without monitoring. Due to the absence of infrastructure entities, various security threats such as unauthorized access, forgery of data, location tracking and address scanning may become more serious. These threats should be considered and mitigated.

Annex A

Service scenario and mechanism of self-organization networking

(This annex forms an integral part of this Recommendation.)

A.1 Service scenario

Self-organization networking (SON) is used to construct local IoT networks, such as home networks and small industry networks, and supports IoT services with peer-to-peer communication models in homogeneous or heterogeneous IoT environments.

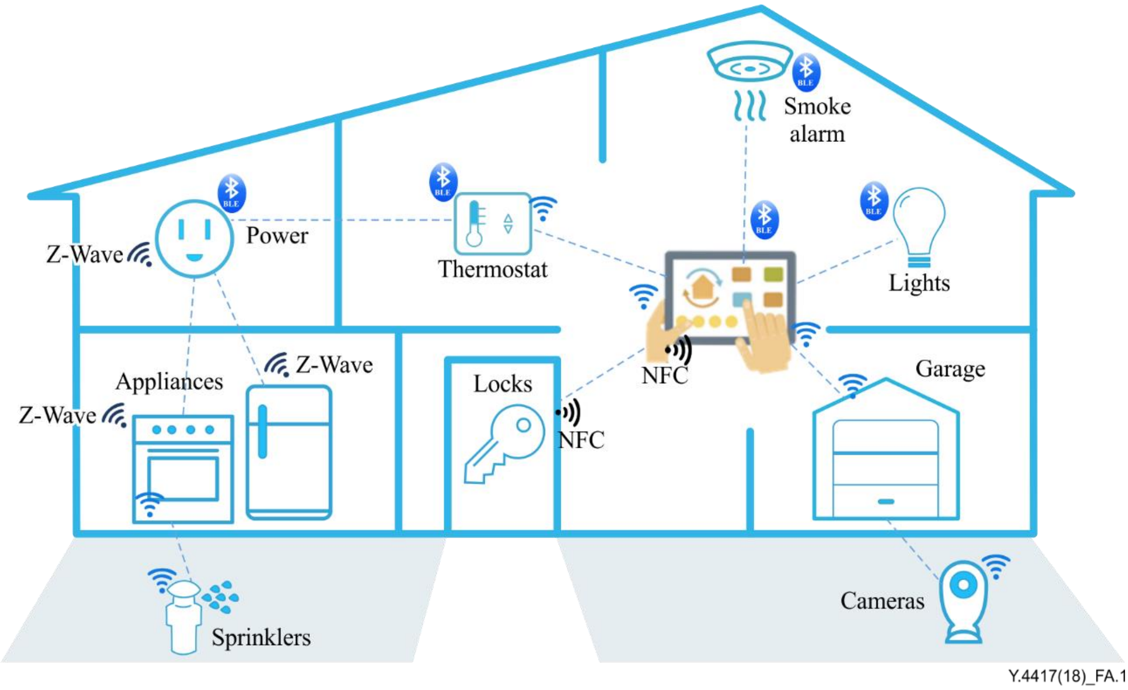


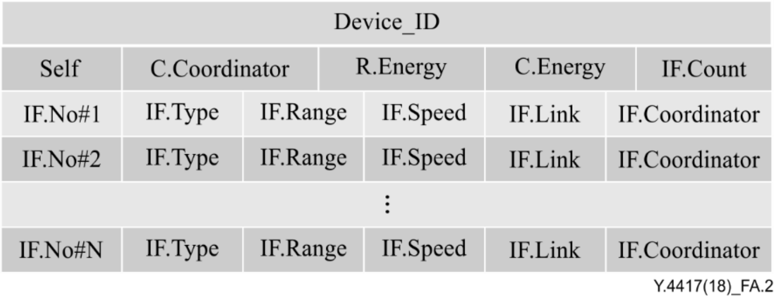
Figure A.1 – Service scenario of SON in smart homes

In Figure A.1, heterogeneous IoT devices, including one or more different networking technologies, such as Bluetooth, NFC, Z-wave and Wi-Fi, are deployed in a smart home. It is assumed that each IoT device has no information about the IoT network and IoT services at the beginning. The functions of SON on each IoT device are activated to gather information about the IoT network and IoT services. During the gathering of information each IoT device acquires some necessary information for building SON. A specific IoT device (including two or more network interfaces) is selected as coordinator and this device serves the coordination functions for other IoT devices. With assistance of the selected coordinators, each IoT device has a capability to construct an infrastructure-unsupported IoT area network. Also, each IoT device has a capability to discover neighbour nodes for possible IoT services, such as remotely controlling and monitoring locks, alarms, lights, thermostats, power and other home appliances. To send and receive data, a corresponding path of end-to-end is determined and peer-to-peer communication is proceeding in the IoT network. The construction of an IoT network and path discovery is proceeded to support IoT services.

A.2 Mechanisms of SON

This clause shows an example of mechanisms for supporting the SON service scenario. The mechanism consists of algorithms for discovering coordinators for SON and building a network.

Every IoT device repeatedly broadcasts its own information as shown in Figure A.2.



<table>
<tr><td colspan="6">Device_ID</td></tr>
<tr><td>Self</td><td colspan="2">C.Coordinator</td><td>R.Energy</td><td>C.Energy</td><td>IF.Count</td></tr>
<tr><td>IF.No#1</td><td>IF.Type</td><td>IF.Range</td><td>IF.Speed</td><td>IF.Link</td><td>IF.Coordinator</td></tr>
<tr><td>IF.No#2</td><td>IF.Type</td><td>IF.Range</td><td>IF.Speed</td><td>IF.Link</td><td>IF.Coordinator</td></tr>
<tr><td colspan="6">⋮</td></tr>
<tr><td>IF.No#N</td><td>IF.Type</td><td>IF.Range</td><td>IF.Speed</td><td>IF.Link</td><td>IF.Coordinator</td></tr>
</table>

Figure A.2 – Device information to broadcast

The information details are as follows:

- ***Device ID***: identifier of device;
- ***Self***: a bit information to set TRUE (or 1) value when a device broadcasts its own information;
- ***C.Coordinator***: a bit information to set TRUE (or 1) value if a device is elected as a candidate for coordinator;
- ***R.Energy***: a ratio of remaining energy;
- ***C.Energy***: a rate of consuming energy for a certain time;
- ***IF.Count***: the number of network interfaces which a device equips;
- ***IF.No#1***: a sequence number to identify network interfaces which a device equips;
- ***IF.Type:*** a name of the network interface;
- ***IF.Range***: RF range of the network interface;
- ***IF.Speed***: data transmission speed (bps);
- ***IF.Link***: a list of connected neighbour devices;
- ***IF.Coordinator***: device ID of a connected coordinator.

Whenever a device receives a neighbour's information, the device discovers candidates for coordinator and connections to build a network from the information by using the following two algorithms. Figure A.3 shows the algorithm to find coordination candidates.

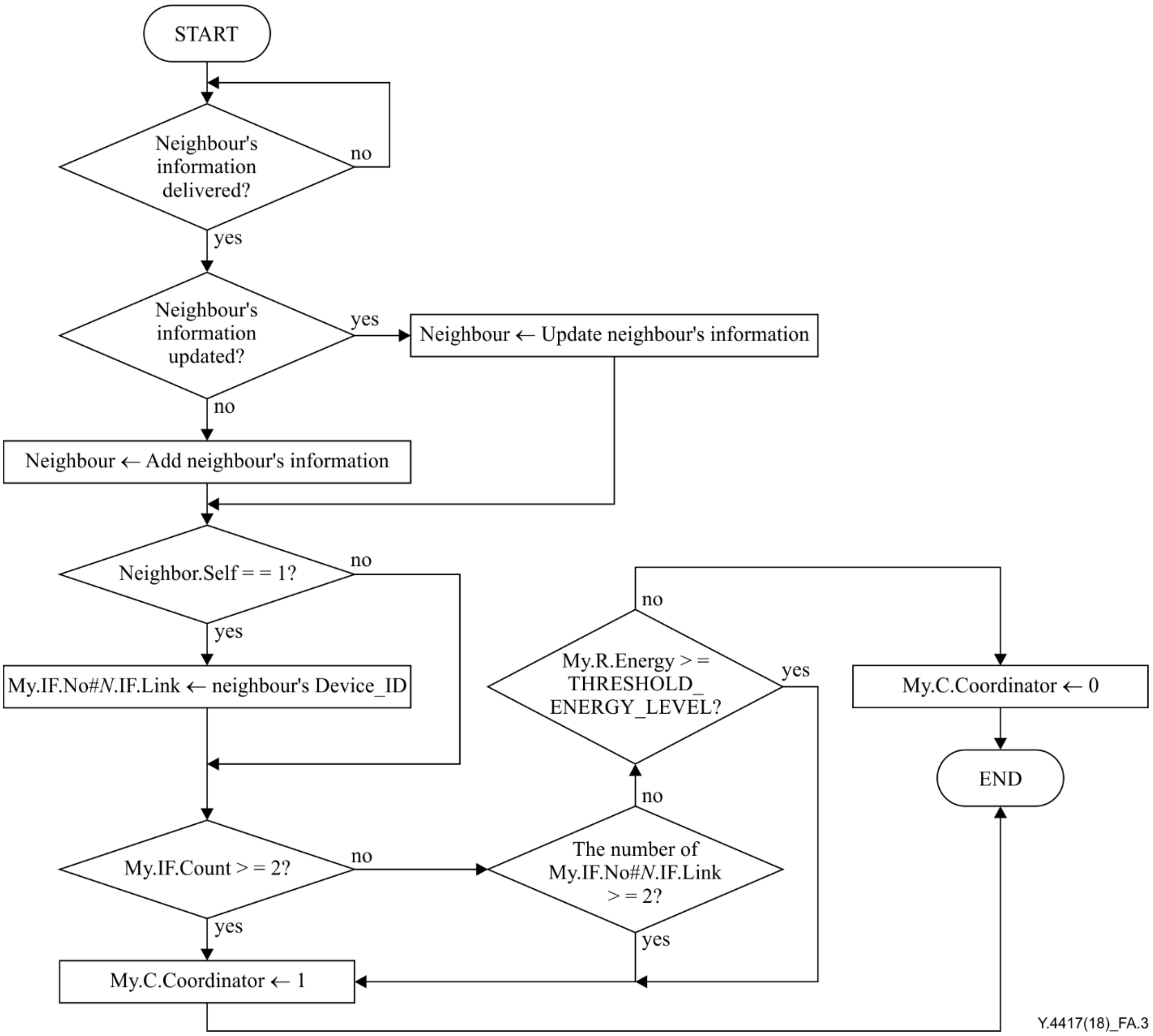


Figure A.3 – Algorithm to discover candidates for coordinators

Devices update their own information with information received by neighbours, and then they broadcast the updated information to neighbours. Through the algorithm (as shown in Figure A.3), coordinator candidates in a network can be discovered in sequence. Devices that equip multiple interfaces or multiple connections can become candidates for coordinator. In addition, energy-efficient devices can become candidates for coordinator if the SON requires energy saving. The "THRESHOLD_ENERGY_LEVEL" in Figure A.3 means a threshold of enough remaining energy level to play the roles of coordinators.

Figure A.4 shows the algorithm to discover connections to build a network.

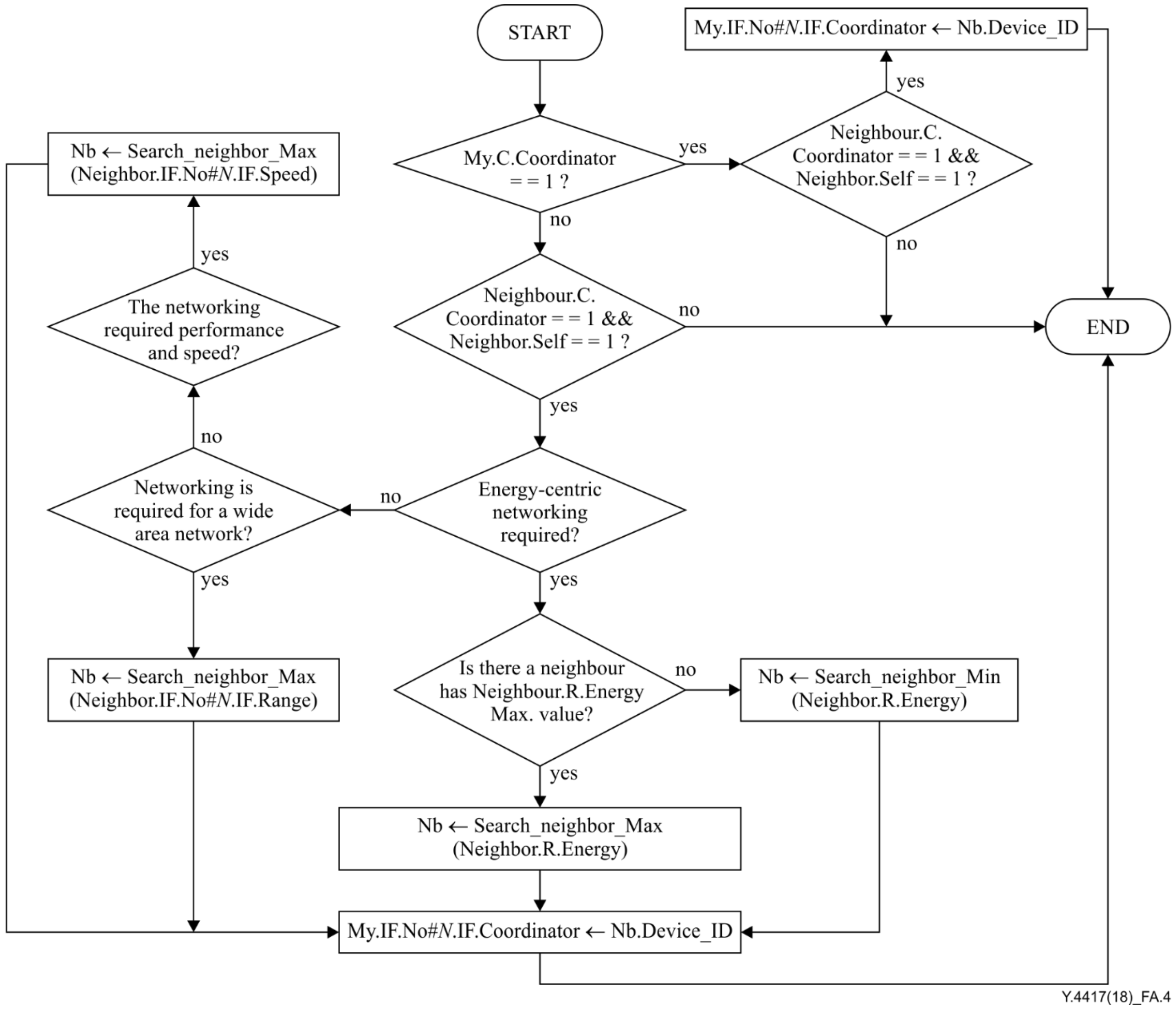


Figure A.4 – Algorithm to discover connections to build a network

If the SON is required to build a network for supporting one of the characteristics, such as energy, throughput and network coverage according to environmental circumstances, coordinators that are appropriate to the characteristics, are selected by exploiting the algorithm in Figure A.4. If SON is required for wide area networks (e.g., LPWAN), candidates which have long range network interfaces, (e.g., LoRa, Sigfox, IEEE802.11ah, WI-SUN, NB-IoT, etc.) should become coordinators.

Appendix I

Related works of self-organization networking

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

The concept of infrastructure-less networks is partially studied in 3GPP Self-Organizing Network (SON) and IEEE Next Generation Service Overlay Network (NGSON). The object of 3GPP SON is to decrease OPEX/CAPEX related to network configuration, operation and optimization. The main functionalities of 3GPP SON is self-configuration (plug and play of new eNodeB), self-healing (e.g., cell outage compensation), and self-optimization (e.g., mobility load balancing, handover optimization, energy saving management, etc.) [b-3GPP TR 36.902].

In the IEEE NGSON, self-organizing networking capabilities are described to develop network structures based on the needs of the customers and the capabilities of existing network structures [b-IEEE P1903]. However, the 3GPP SON is related to only a mobile communication network and IEEE NGSON is related to only NGSON architecture.

[b-ETSI GS AFI] defines, iteratively, a generic, conceptual architectural reference model intended to serve as guidelines for the design of the future generation networks exhibiting autonomic characteristics or capabilities. ETSI GS AFI defines the generic autonomic network architecture (GANA) reference model for autonomic network engineering, cognitive networking and self-management. The GANA model is a conceptual architectural reference model for autonomic network engineering, cognition and self-management.

A similar study is done in the IETF. In the Autonomic Networking Integrated Model and Approach (ANIMA) working group, autonomic networking refers to the self-managing characteristics (configuration, protection, healing and optimization) of distributed network elements, adapting to unpredictable changes while hiding intrinsic complexity from operators and users. An autonomic function that works in a distributed way across various network elements is a candidate for protocol design. Such functions should allow central guidance and reporting, and coexistence with non-autonomic methods of management. The general objective of this working group is to enable the progressive introduction of autonomic functions into operational networks, as well as reusable autonomic network infrastructure, in order to reduce the operational expense [b-IETF ANIMA]. The IETF Mobile Ad-hoc Networks (MANET) working group is to standardize IP routing protocol functionality suitable for wireless routing application within either static and dynamic topologies with increased dynamics due to node motion or other factors [b-IETF MANET]. In the IETF Ad-hoc Network Auto-configuration (AUTOCONF) working group, it standardized how existing IPv6 address configuration tools can be used for address configuration in an ad-hoc model [b-IETF AUTOCONF].

In the IEEE 802.11 area, the independent basic service set (IBSS) or ad-hoc network is a network where WLAN stations communicate only through peer-to-peer without the operations of an access point. The ad-hoc network in the Wi-Fi area is spontaneous and can be set up rapidly. Wi-Fi direct technology that enables Wi-Fi devices to connect directly, making it simple and convenient to do things like print, share, sync and display was developed in the Wi-Fi Alliance.

In the ITU-T, distributed service networking (DSN) is defined as overlay networking which provides distributed and manageable capabilities to support various multimedia services and applications [b-ITU-T Y.2206]. DSN is based upon the use of a collection of nodes organized in a peer-to-peer (P2P) or other distributed fashion and the links between the nodes for the purpose of enabling multimedia services and applications. It is assumed that DSN is an overlay above IP. Collectively, the nodes provide a distributed mechanism. DSN also provides capabilities for application layer QoS support.

The SON is defined as "An autonomous networking established by each device, where the device can effectively interact with its peers and perform self-control for network-organization and joining network according to its own status, own service and dynamic network circumstance in a decentralized infrastructure or infrastructure-less". The similar concept was proposed and developed as many areas such as 3GPP SON, IEEE NGSON, ETSI GS AFI, IETF ANIMA, MANET, AUTOCONF, IEEE 802.11 ad-hoc, Wi-Fi Direct, and ITU-T distributed service networking (DSN). Table I.1 shows the features of each mechanism.

Table I.1 – Related works of SON

Terms	Standardization body	Object	Scope
Self-Organizing Network (SON)	3GPP	Decrease OPEX/CAPEX related to network configuration, operation and optimization	Mobile communication network
Next Generation Service Overlay Network (NGSON)	IEEE	Develop network structures based on the needs of the customers and the capabilities of existing network structures	NGSON architecture
Autonomic network engineering for the self-managing Future Internet (AFI)	ETSI	Defines a generic, conceptual architectural reference model	Generic autonomic network architecture (GANA) reference mode
Autonomic Networking Integrated Model and Approach (ANIMA)	IETF	Develop autonomic networking of distributed network elements, adapting to unpredictable changes while hiding intrinsic complexity from operators and users	Autonomic network infrastructure
Mobile Ad-hoc Networks (MANET)	IETF	Develop IP routing protocol functionality suitable for wireless routing application within	Static and dynamic topologies with increased dynamics due to node motion or other factors
Ad-hoc Network Autoconfiguration (AUTOCONF)	IETF	Develop IPv6 address configuration tools can be used for address configuration in ad-hoc model	Conventional Internet
Independent Basic Service Set (IBSS)	IEEE	Develop the mechanism of WLAN stations communicating only peer-to-peer without the operations of an access point	IEEE 802.11 world
Distributed service networking (DSN)	ITU-T	Define an overlay networking which provides distributed and manageable capabilities to support various multimedia services and applications	The use of a collection of nodes organized in a peer-to-peer (P2P) or other distributed fashion and the links

Although self-organizing network, autonomic network, ad-hoc network, and DSN have been developed in various areas, these technologies have some restrictions to apply in IoT environments because they do not consider the characteristics of the IoT environments. So, it is needed to study a SON (including self-organizing network, autonomic network, ad-hoc network, and DSN) in a general network point of view and for IoT environments.

Bibliography

[b-ITU-T Y.2206]	Recommendation ITU-T Y.2206 (2010), *Requirements for distributed service networking*.
[b-3GPP TR 36.902]	3GPP TR 36.902 (2009), *Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Self-configuring and self-optimizing network (SON) use cases and solutions*.
[b-ETSI GS AFI]	ETSI GS AFI 002 v1.1.1 (2013), *Autonomic network engineering for the self-managing Future Internet (AFI); Generic Autonomic Network Architecture (An Architectural Reference Model for Autonomic Networking, Cognitive Networking and Self-Management).*
[b-IEEE P1903]	IEEE P1903 (2011), *Next Generation Service Overlay Network.*
[b-IETF ANIMA]	IETF Autonomic Networking Integrated Model and Approach (anima) working group. http://datatracker.ietf.org/wg/anima/charter/
[b-IETF AUTOCONF]	IETF AUTOCONF, *Ad-hoc Network Autoconfiguration Working Group*. http://datatracker.ietf.org/wg/autoconf/charter/
[b-IETF Autonomic Netw]	M. Behringer, M. Pritikin, S. Bjarnason, A. Clemm, B. Carpenter, S. Jiang, L. Ciavaglia (2015), *Autonomic Networking –Definitions and Design Goals*.
[b-IETF MANET]	IETF MANET, *Mobile Ad-hoc Networks Working Group.* http://datatracker.ietf.org/wg/manet/charter/

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series D	Tariff and accounting principles and international telecommunication/ICT economic and policy issues
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	Transmission systems and media, digital systems and networks
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	Cable networks and transmission of television, sound programme and other multimedia signals
Series K	Protection against interference
Series L	Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant
Series M	Telecommunication management, including TMN and network maintenance
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Telephone transmission quality, telephone installations, local line networks
Series Q	Switching and signalling, and associated measurements and tests
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks, open system communications and security
Series Y	**Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities**
Series Z	Languages and general software aspects for telecommunication systems

Printed in Switzerland
Geneva, 2018