
**Telecommunications and information
exchange between systems — Future
network architecture —**

**Part 3:
Networking of everything**

*Télécommunications et échange d'informations entre systèmes —
Architecture du réseau du futur —*

Partie 3: Réseautique universelle

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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

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This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 6, *Telecommunications and information exchange between systems*.

A list of all parts in the ISO 21558 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html and www.iec.ch/national-committees.

Introduction

This document specifies the Future Network – Networking of everything (FN-NoE) architecture, which is designed to provide further advanced NoE services identified in ISO/IEC TR 29181-9.

ISO/IEC TR 29181-9 is part of the ISO/IEC TR 29181 series of standards on Future Network (FN). ISO/IEC TR 29181-9, which addresses networking issues raised in ISO/IEC TR 29181-1, covers networking of everything.

The scope of this document focuses on the FN-NoE architecture, consisting of access and core networks, thing social networks, and proximity defined networks, in which smart devices participate.

This document provides the general characteristics of NoE which can be applied to future networks such as RINA as shown in [Annex B](#), especially from an Internet of Things (IoT) perspective, through a conceptual model of NoE.

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Telecommunications and information exchange between systems — Future network architecture —

Part 3: Networking of everything

1 Scope

This document focuses on networking issues for integrating various networking technologies for integrating various networking techniques to provide the thing-user centric communication service.

This document specifies:

- the architectural model of the Future Network – Networking of Everything (FN-NoE);
- the functional procedure for providing advanced FN-NoE services that integrate various networks.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC/TR 29181-9:2017, *Information technology — Future Network — Problem statement and requirements — Part 9: Networking of everything*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC TR 29181-9 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1

object

intrinsic representation of an entity that is described at an appropriate level of abstraction in terms of its attributes and functions

[SOURCE: ISO/IEC TR 29181-9:2017, 3.12]

3.2

context

information that can be used to characterize the environment of a user

[SOURCE: ISO/IEC TR 29181-9:2017, 3.4]

3.3 thing

object of the physical world (physical things) or of the information world (virtual thing), which is capable of being identified and integrated into communication networks.

Note 1 to entry: Physical things are capable of being sensed, actuated, and connected to things such as robots, goods, and electrical equipment. Virtual things are capable of being stored, processed, and accessed by things such as multimedia content and application software.

[SOURCE: ISO/IEC TR 29181-9:2017, 3.16]

3.4 Internet of Things

IoT

global infrastructure for the information society enabling advanced services by interconnecting (physical and virtual) things based on existing or evolving interoperable information and communication technologies

[SOURCE: ISO/IEC TR 29181-9:2017, 3.8]

3.5 collaborative work group

group of thing users that can perform job planning, thing user recruitment, and coordination without human intervention

[SOURCE: ISO/IEC TR 29181-9:2017, 3.2]

3.6 proximity defined network PDN

network configured among devices in close proximity, using conventional LAN or WAN technologies: which are in not only physically close proximity, but also closely related, or logically close proximity

Note 1 to entry: PDN is an instantaneous network that is formed during the networking of everything.

[SOURCE: ISO/IEC TR 29181-9:2017, 3.13, modified — Note 1 to entry added.]

3.7 identifier

series of digits, characters, and symbols or any other form of data used to identify a subscriber(s), a user(s), a network element(s), function(s), a network entity(es) providing services/applications, or other entities, e.g. physical or logical objects

Note 1 to entry: An identifier can also be a string of bits bound to an object that may be used to locate an object in a given context.

3.8 Future Network for Networking of Everything FN-NoE

network that is capable of providing thing-user social networking and thing-user centric communication service to the thing-users

3.9 profile

all or some of the information statements about a thing-user, including (1) basic statements including Name, Identity, Address, URI, Account, Contract, Security; (2) motivation statements describing why the thing-user joins the social network; (3) mission statements describing what the thing-user plans to accomplish; or (4) its capacity statements which describe its predications, knowledge, resources

3.10**thing-user**

thing that uses the Future Network for Networking of Everything (FN-NoE) network service or the FN-NoE services provided by other things

3.11**everything**

equipment that is capable of performing Networking of Everything (NoE)

Note 1 to entry: "Everything" can be regarded as anything which can perform NoE in Future Network (FN).

3.12**Networking of Everything****NoE**

process that is capable of providing Future Network for Networking of Everything (FN-NoE) services

3.13**Network of Everything (NoE) terminal**

thing that can perform the process in the network capable of providing thing-user social networking and thing-user centric communication service to the thing-users

3.14**thing-user social network**

social network among thing-users which automatically shares its capabilities, context, communicative motivation, experiences, and intentions of collaboration for delivering the intelligent super-realistic service

Note 1 to entry: As the thing-user expands the social network, it may expand its knowledge.

Note 2 to entry: Thing-user social networking service can be a web application that thing-users use to build a social network provided by Networking of Everything (NoE).

3.15**thing-user centric communication**

process of conveying intended meanings from one thing-user to another thing-user or thing-user group through the use of mutually understood language

3.16**thing-user centric network**

network that allows a thing-user to discover another thing-user or thing-user group who understands its intention conveyed from the thing-user and supports the thing-user in achieving its mission

4 Abbreviated terms

FN	Future Network
FN-NoE	Future Network for Networking of Everything
ID	IDentifier
IoT	Internet of Things
NoE	Networking of Everything
PDN	Proximity Defined Networks
SAP	Service Access Point
TSN	Thing-user Social Network

URI Uniform Resource Identifier

URL Uniform Resource Locator

5 Future Networks — Networking of Everything (FN-NoE)

5.1 General

Networking of Everything (NoE) refers to the process capable of providing FN-NoE services such as thing-user social networking and thing-user centric communication services to the thing users who participate in the FN-NoE.

FN-NoE provides a functional procedure that integrates various networking technologies through social networking among thing-users and provides user-centric communication. This document defines an architectural model of the FN-NoE and serves as a companion document to ISO/IEC 21559-3 for protocol and mechanisms specifying control protocols of the FN-NoE.

For the time being, since the deployment of FN-NoE will be very limited geographically or technically until more advanced applications for IoT emerge in the market, FN-NoE shall coexist with the conventional networks. FN-NoE is regarded as (connected) islands in the sea of the Internet, as shown in the [Figure 1](#).

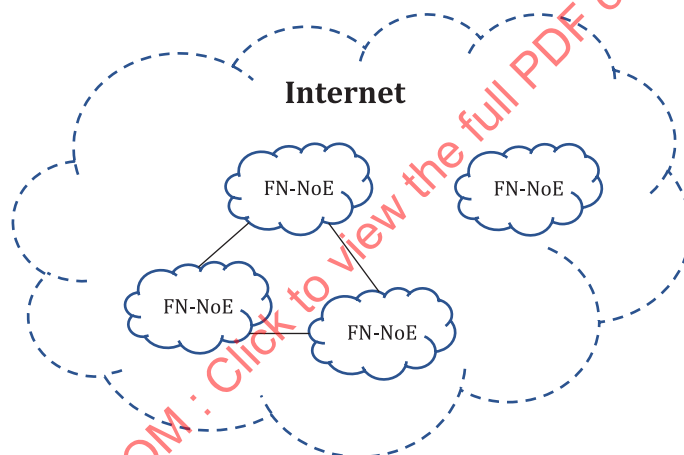


Figure 1 — Deployment of FN-NoE in the Internet

5.2 Thing-user social networking

A thing can be an intelligent thing-user that describes its sensing information, shares the acquired experience or knowledge with other things, and leverages the capabilities provided by other thing users. A thing will become a thing-user of the FN-NoE by having its physical entity or logical entity that performs a task with an equipped major skill-set and optional-skill set. The thing-user will have the expertise built on its experience performing tasks using specific domain-related knowledge. The thing-user may be classified according to the equipped skill set and expertise domain.

Thing-users can form a thing-user social network to share:

- basic information for communication of its device, e.g. ID, address, URI or URL, security (described in Basic statements),
- their capabilities (described in Capability statements in Profile),
- context,
- communicative motivation (described in Motivation statements),

- e) experiences,
- f) intentions of collaboration for delivering the intelligent super-realistic service (described in Mission statements).

To understand and share this information, each thing-user should use the language that computers understand, e.g. semantics to describe diverse context, standard DB structure to store, retrieve.

The central aspect of thing-user social networking is very similar to human social networking. The only difference is that each device or computer understands the social information through semantic language [4],[5] All such information is defined based on FN-NoE ontology and is updated continuously by a third party.

After a thing-user is initiated, it searches for social networks which fit its context and objectives, joins them, and shares its information with other thing-users that have already joined as partners. Depending on its context, a thing-user can join two or more social networks at the same time. While performing collaborative work with other thing-users, if a thing-user needs further information, it may request that its partners contact their partners to resolve it. This search process may repeat recursively.

5.3 Thing-user centric communication service

In the FN-NoE, the thing-user is intelligent and socialized to interact with other thing-users autonomously. In addition to producing digitalized information, thing-users also produce varieties of reactions based on a socialized decision. The thing-user describes communicative motivation or goals and conveys intended meanings to other thing-users or thing-user groups through mutually understood language. From the thing-user communities, the thing-user discovers another thing-user or thing-users capable of collaborating to accomplish its communicative goal as a human-user does. One of the service use-cases is shown in [Annex A](#).

The FN-NoE provides a structure in which a thing-user discovers and coordinates thing-users among the socialized things located within a space to autonomously perform collaborative work.

6 Architecture of FN-NoE

6.1 General

The infrastructure for the FN-NoE is constructed by the access networks, the core networks, and the regional networks. The access networks and the core networks are evolved from the current networks. The FN-NoE is operated over either existing legacy networks or future networks. An NoE terminal located in a certain space connects to an access network. It is connected to another NoE terminal through the core networks and an access network.

Different network operators may operate the core networks between NoE terminals. The switching and routing schemes applied to the core networks may be different. The access network is managed by the core network operator. The access network is differentiated by the type of access links and access procedures. The access network may have a local network managed by the local private owner as a subnetwork. The local network may have a local network underneath it.

[Figure 2](#) shows a reference network model in which multiple NoE terminals located in a particular space are connected, as shown in [Figure 1](#). There is an NoE terminal connected to the A type access network of the core network managed by the operator X. There is an NoE terminal connected to the B type access network of the core network managed by the operator Y. There is an NoE terminal connected to the C type local network operated by the local operator, connected to the B type access network of the core network managed by the operator Y. There is an NoE terminal connected to the D type local network operated by the local operator, connected to the C type local network operated by the local operator, connected to the B type access network of the core network managed by the operator Y.

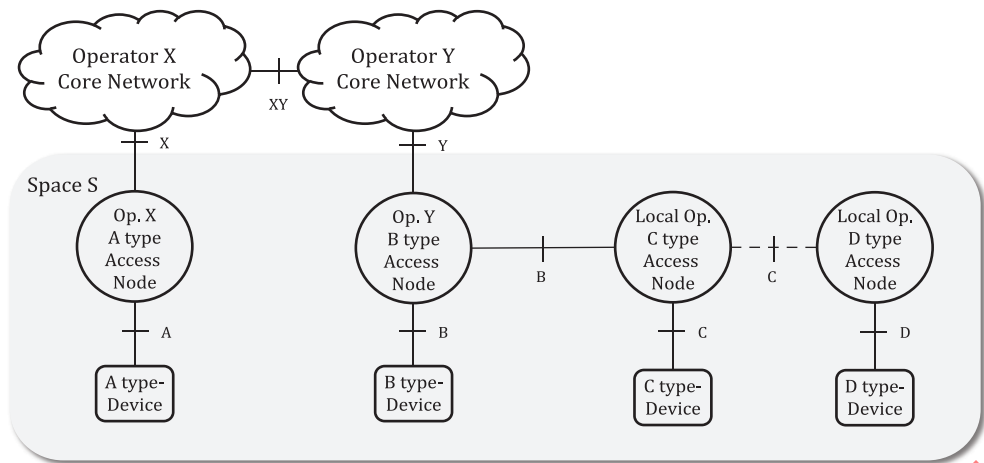


Figure 2 — FN-NoE operated over existing legacy networks

The FN-NoE provides a thing-to-thing connection for coordinating NoE terminals connected to heterogeneous access networks. The FN-NoE defines the coordinated networking layer, in which the NoE terminals can socialize with each other for sharing the coordination experience and performing context-based discovery, as shown in [Figure 3](#). The coordinated networking layer locates between application layer and transport/network layer.

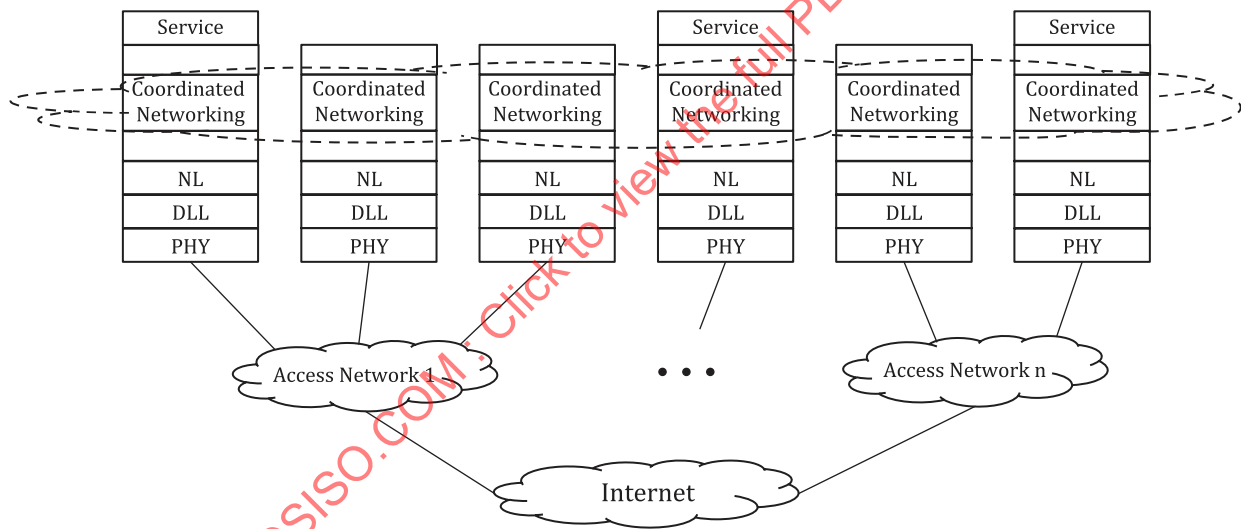


Figure 3 — FN-NoE layered architecture based on conventional OSI network

The regional network is a virtual network that provides logical access to an intelligent socialized thing-user. The regional networks overlay with the access networks and the core networks. The regional networks consist of the NoE terminals and the NoE virtual switches. They can either concurrently work to an NoE terminal or dedicate themselves to thing-users.

The coordinated networking layer is implemented in the NoE terminals and the NoE virtual switches of the regional networks, as shown in [Figure 4](#). The NoE virtual switch has a position to share the coordination information among the NoE terminals. The regional virtual switch is nominated by the NoE terminals or network devices that implement the NoE coordinated networking layer. The overlay virtual switch is nominated by the regional virtual switches.

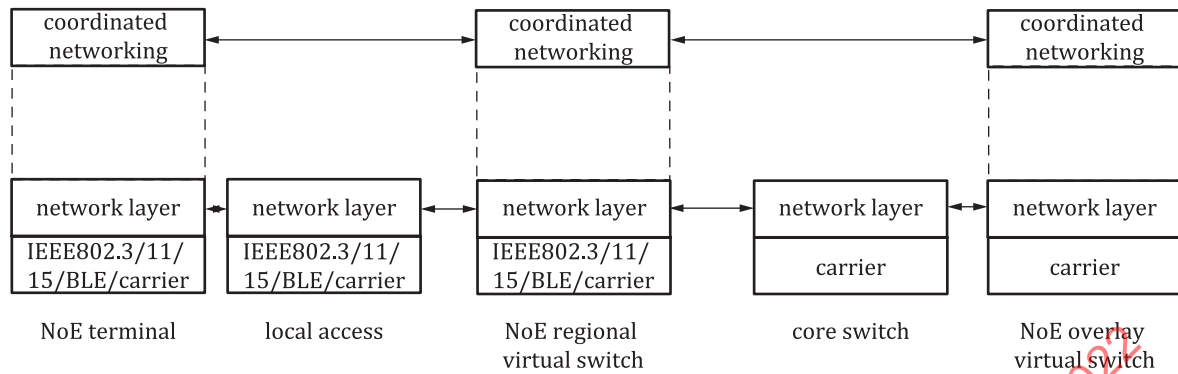


Figure 4 — Example of connections in the FN-NoE

6.2 FN-NoE for thing-user centric communication service

The thing-user centric network provides a thing-to-thing connection that can support autonomous coordination between the NoE terminals located in proximity to each other. In the thing-user centric network, the NoE terminal communicates as a thing-user with another thing-user or a thing-user group by conveying intended meaning using the mutually understood language. The thing-user describes the communicative motivation or experience to perform a specific task using the thing-user language, based on the task-related domain ontology.

The thing-user may form a thing-user social group to share experiences with thing-users located in its proximity or with thing-users sharing the same interest. The thing-users are autonomous and have equal rights to govern the thing-user social group. The thing-users share equally the resources necessary for the operation and maintenance of the social group. The goal of a thing-user social group and thing-user experiences are described in domain ontology-based semantic language.

The thing-user may join a thing-user social group or invite another thing-user to join a thing-user social group. The thing-user subscribes to a thing-user or a thing-user group to harvest the knowledge needed to perform a task.

The thing-user discovers a communication party relying on the assistance of thing-users in a thing-user social group. The thing-user requests that other thing-users of a thing-user group introduce a thing-user who may be the communicative correspondent or may know the communicative correspondent. The thing-user continues these referral requests until it meets the right communication party. Social assistance is accepted based upon the trustworthiness and reputation a thing-user has established within a social group.

In the thing-user centric network, each of the NoE terminals maintains autonomous social coordination information. The NoE terminal may share the coordination information with the NoE terminals located within the same space or exchange coordination information over regional virtual switches and overlay virtual switches.

The NoE terminal, the regional virtual switch, and the overlay virtual switch maintain social coordination information fully distributed manners. Autonomous social coordination information can be searched on the flat web service architecture consisting of NoE terminals, regional virtual switches, and overlay virtual switches. The overlay virtual switch is used for exchanging coordination information between regional virtual switches.

In the FN-NoE for the thing-user centric communication, an NoE terminal can be a thing or a thing-user, possibly acting as a regional virtual switch or an overlay virtual switch as shown in [Figure 5](#). It can be a perception of NoE virtual circuit in [Figure 5](#).

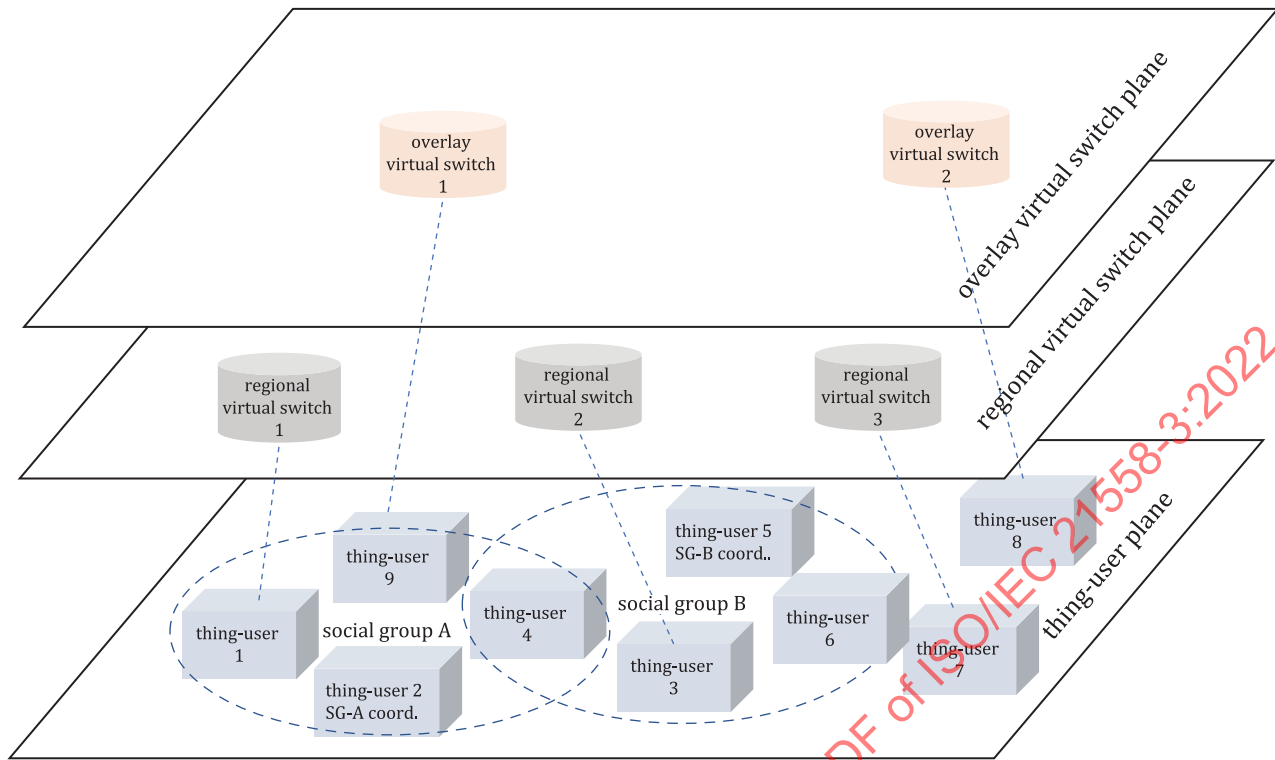


Figure 5 — Example of geographical distribution of thing-users, thing-user social groups, and virtual switches

6.3 Topologies of the FN-NoE

The components of the FN-NoE are:

- a thing-user that performs in an NoE terminal or an NoE virtual switch,
- transport networks that provide physical connections to NoE terminals and NoE virtual switches. The FN-NoE is composed of the physical network and logical networks. The physical network of the FN-NoE can be the heterogeneous network implemented in legacy networks. The Thing-user Social Network (TSN) and the Proximity Defined Network (PDN) are the logical networks of the FN-NoE.

As shown in [Figure 6](#), nodes and thing-users are in the scope of three different types of access networks. They may or may not communicate with each other over the heterogeneous network. The thing-users form thing-user communities and share their experiences over the TSNs.

The NoE terminal requests a thing-user centric communication service while providing a communicative motivation described in thing-user language. FN-NoE consults with an NoE virtual switch in a social network to discover a thing-user or thing-user group to achieve the goal.

The PDN consists of thing-users and virtual switches joining TSNs. In [Figure 6](#), we see that when a node in legacy networks usually accesses the local network 1, it can communicate with a node in network 3 only if the node knows its destination network address (or name). Networks should be interconnected via intermediate nodes. However, when thing-user 1 in FN-NoE joins an appropriate social network 1 depending on its profile and communicative motivation, it can locate the exact thing-user in network 3, not by a network-dependent routing algorithm, but by context-aware social networking. Through this thing-user social networking, a thing-user centric communication service is provided to the thing-user, which is only identified by a profile or name (not a network address).

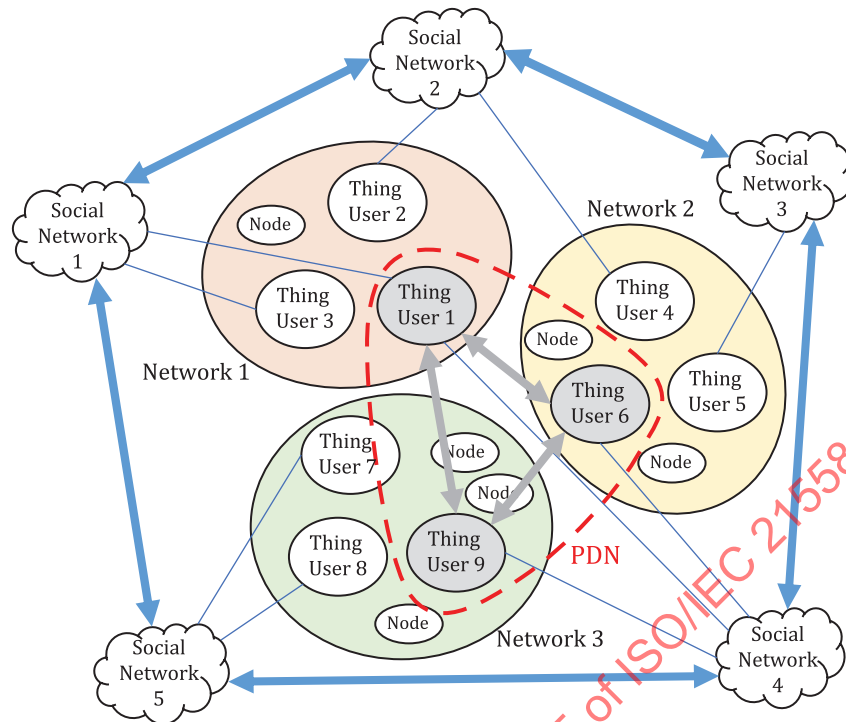


Figure 6 — Networking example of the FN-NoE

6.4 Reference model of the FN-NoE

A FN-NoE terminal comprises an application service layer, a coordinated networking layer, and a transport network layer, as shown in Figure 7. The coordinated networking layer consists of a Thing-user Service Control sublayer, a Thing-user Social Network sublayer, and a Proximity Defined Network sublayer. The definitions of “application service layer” and “transport network layer” are outside the scope of this document.

The Thing-user Service Control sublayer provides NoE service to the Application Service layer through the NoE service access point (NoE SAP). This sublayer maintains its own profile as the thing-user of the NoE terminal and controls the execution of thing-user centric communication services.

The Thing-User Social Network sublayer provides the social network service to the Thing-user Service Control sublayer through the Thing-user Social Network service access point (TSN SAP). This sublayer provides the thing-user social community organizing service, the thing-user experience sharing service, and the thing-user collaboration service.

The Proximity Defined Network sublayer provides the proximity defined network service to the Thing-user Service Control sublayer through the Proximity Defined Network service access point (PDN SAP). This sublayer provides the proximal discovery service and the proximal path management service.

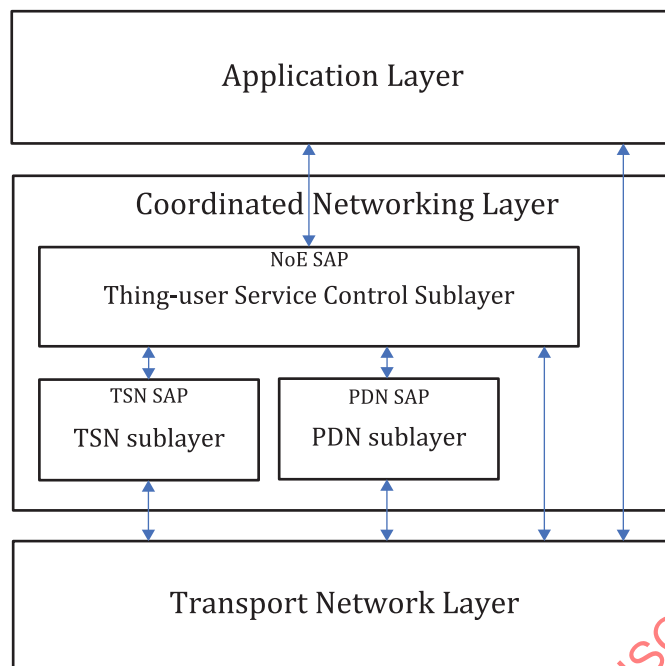


Figure 7 — FN-NoE terminal architecture

To provide autonomous coordinated thing-to-thing connections between the NoE terminals, the FN-NoE specifies the following:

- how to manage the NoE terminal, regional virtual switch, and overlay virtual switch,
- how to form a thing-user social community,
- how to share experience with thing-users,
- how to discover a thing or thing-user for collaboration,
- how to establish a proximal path between the NoE terminals,
- how to establish coordinated connections among the NoE terminals.

The Coordinated Networking Layer of the FN-NoE is composed of the following capability blocks, as shown in Figure 8: the NoE terminal thing-user management; thing-user centric networking control; thing-user social networking; coordinated experience management; coordinated peer discovery; and proximal path management.

- **The NoE terminal thing-user management** block maintains the profile and the status of the NoE terminal's resources and capability skill set. This block manages the NoE terminal, regional virtual switch, and overlay virtual switch as a thing-user.
- **The thing-user centric networking control** block manages the process of socializing a thing-user and establishing a thing-to-thing connection.
- **The thing-user social networking** block performs the process of organizing or disbanding a thing-user social community. This block controls an NoE terminal to join or leave a thing-user social community. This block controls an NoE terminal to publish or subscribe to an experience sharing with a thing-user social community. The control protocols between the NoE terminal social networking blocks are defined at the reference point R2.
- **The coordinated experience management** block maintains the coordinated networking experienced by the NoE terminal and by the NoE terminals of joined thing-user social communities.

This block searches the experience base to match a request from an NoE terminal or a thing-user social community.

- **The coordinated peer discovery** block performs the process of discovering a peer NoE terminal or the NoE terminals with which to form a collaborative work group. This block searches for a proximal NoE terminal from a thing-user social community, or it hands over the discovery to the regional virtual switches or overlay virtual switches.
- **The proximal path management** block constructs a route between two proximal end points specified by the thing-user service control sublayer through the transport network layer and provides interworking between heterogeneous operating routes. The control protocols between the proximal path management blocks are defined at the reference point R1.

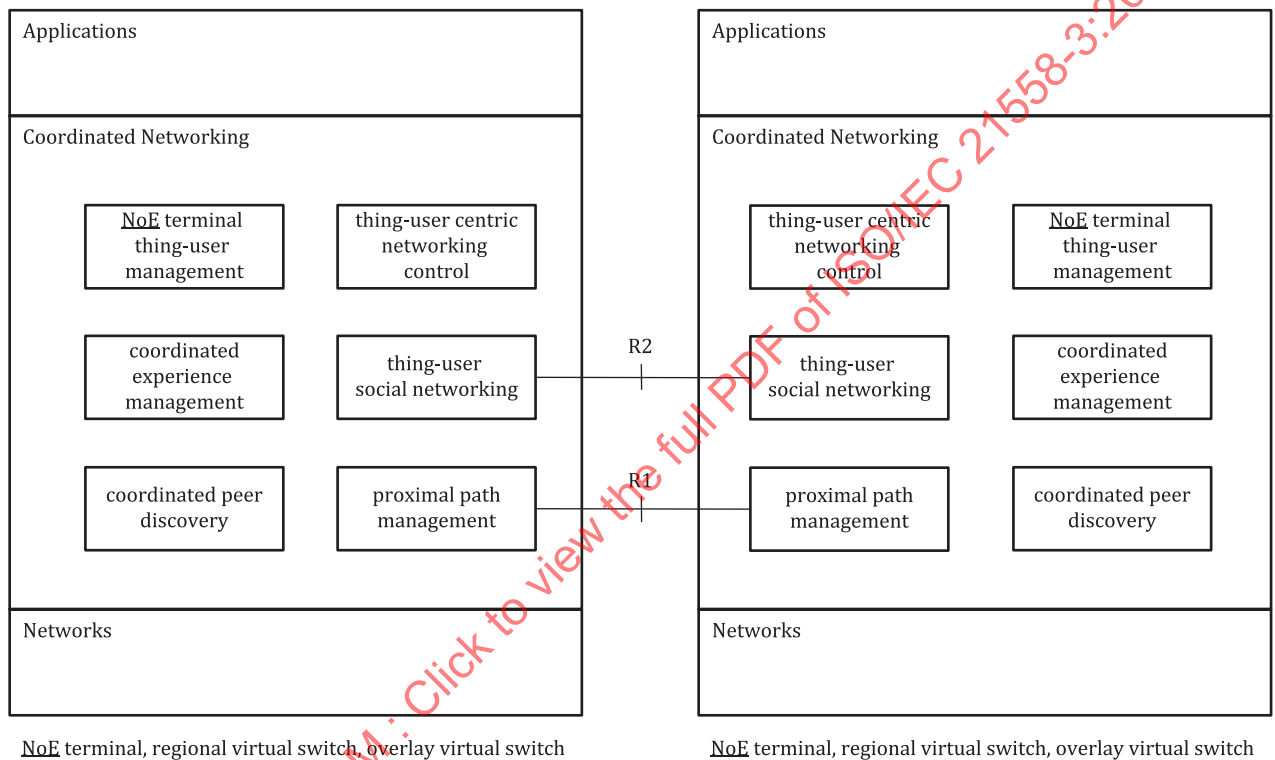


Figure 8 — Reference model of the FN-NoE

7 Functional procedure of the FN-NoE

7.1 General

The functional features of the FN-NoE are:

- organization and maintenance of the thing-user social community;
- sharing thing-user experiences in the thing-user social community;
- finding the coordinated thing-user;
- establishing and maintaining the proximal path.

NOTE [Annex A](#) describes how the FN-NoE provides a thing-user centric communication service. [Annex B](#) shows how the FN-NoE is operated over Recursive InterNetwork Architecture.

7.2 Thing-user and thing-user social community

The thing-user is an object representing an NoE terminal or a virtual switch in the FN-NoE. The thing-user manages the resources of an NoE terminal or a virtual switch.

These resources include profiles on identities, capability skill sets, and miscellaneous information on an NoE terminal. The thing-user owns the properties such as experience and knowledge data produced by an NoE terminal or a virtual switch.

The thing-user may organize the thing-user social community to share experiences or collaborate on mission accomplishment. The thing-users are autonomous and have equal rights to govern the thing-user social community. The thing-users share equally the resources necessary for the operation and maintenance of the social community.

The thing-user social community is organized to solve a specific mission or to share a particular experience. The goal of a thing-user social community is described by the semantic web language. The thing-user social community has a procedure for consensus decision making and for distributing shared information. The thing-user social community has a process to earn social capital marked by reciprocity, trust and cooperation when producing services for a community goal.

The thing-user social community has a vine and cluster structure, as shown in [Figure 9](#). The cluster of a thing-user social community is built based on the cultural and geographical relation between its thing-users. The cluster is organized and maintained by the cluster coordinator, who is elected from among the cluster members.

A community tier coordinator elected by the tier sub-coordinator and the tier cluster coordinators unites thing-user social community clusters. The cluster members elect the tier cluster coordinator. The thing-user social community may have a multi-tiered community, as shown in [Figure 10](#).

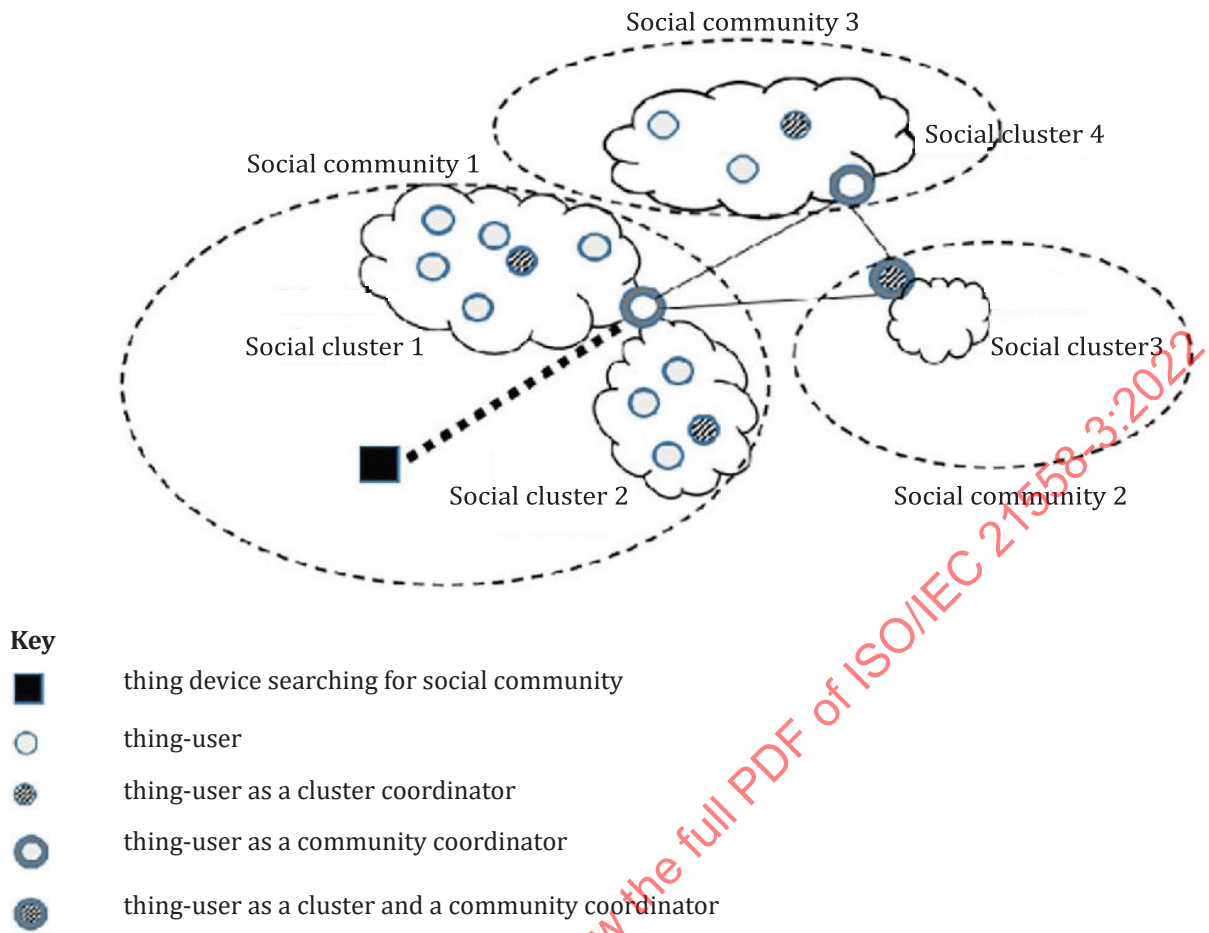


Figure 9 — Structure of thing-user social community

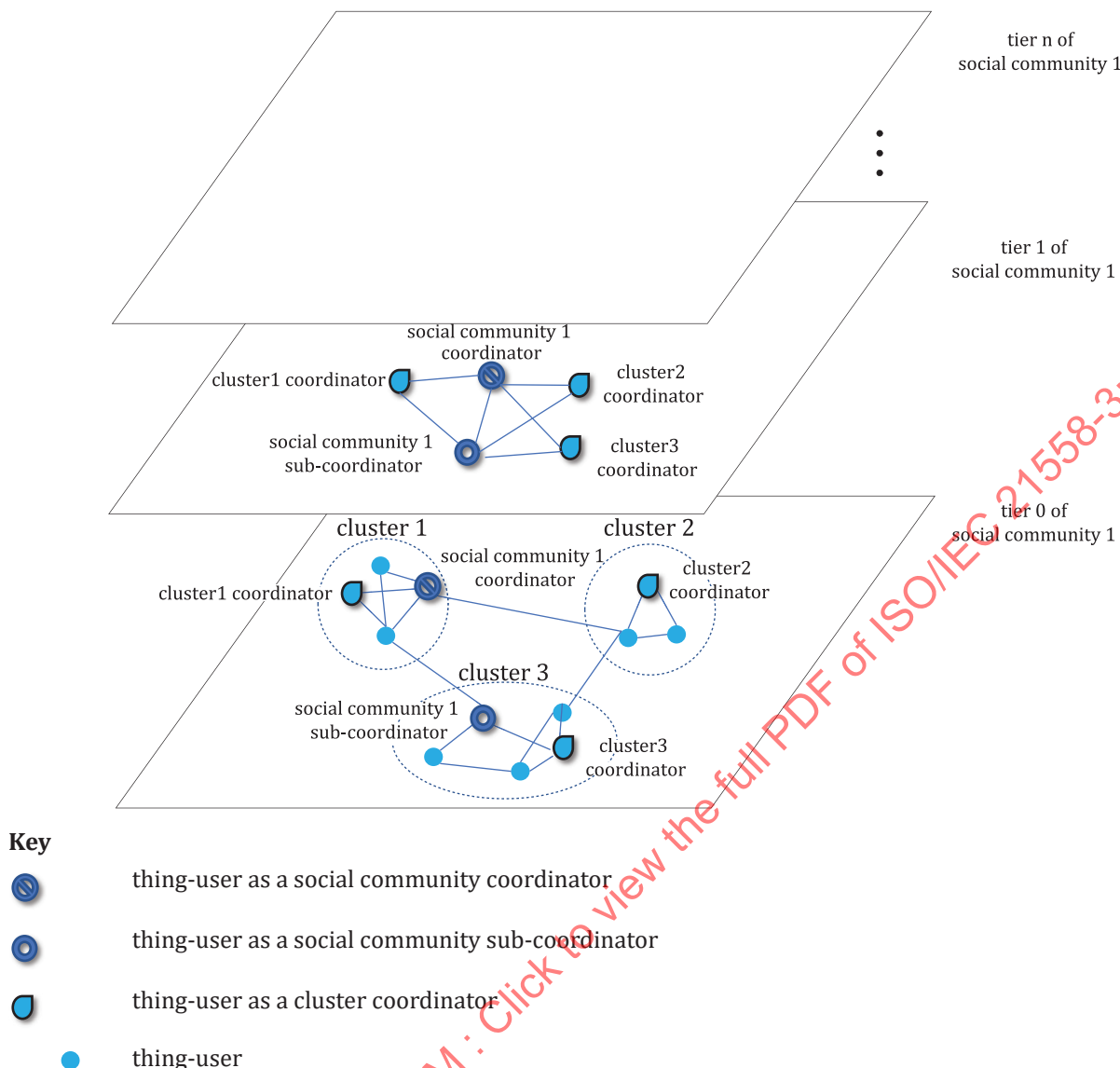


Figure 10 — Multi-tiered structure of thing-user social community

7.3 Organizing and maintaining the thing-user social community

The thing-user of an NoE terminal or a virtual switch is initially specified with a profile.

When a new thing-user is initiated for the first time, the thing-user visits well-known resources, such as the FN-NoE registry, to check whether an appropriate thing-user social community exists nearby with which to collaborate later to accomplish its mission.

If the thing-user finds a coordinator of the social community to accomplish the mission of the thing-user, the thing-user sends a message to join the social community, as shown [Figure 9](#). The coordinator of the social community selects a cluster to join. The community coordinator and sub-coordinator maintain the cluster and coordinators of clusters.

If the thing-user fails to find a thing-user social community, the thing-user organizes its thing-user social community and becomes a community coordinator. The community coordinator checks in the FN-NoE registry by reporting its identities as a coordinator and its mission statement. The first community coordinator becomes the cluster coordinator until the cluster is renewed after joining with another thing-user.

The cluster of a social community may be renewed by electing a cluster coordinator periodically. The community tier of a social community may also be renewed by selecting a community tier coordinator periodically.

When a thing-user requests to leave a social community, the cluster coordinator updates the list of cluster members. If the thing-user that requested to leave is the last thing-user of the social community, the thing-user checks out of the FN-NoE registry.

7.4 Sharing thing-user experiences in the thing-user social community

The experience of a thing-user is captured and shared with the thing-user social community in a distributed manner. A cluster member may subscribe to an experience report from other cluster members. The cluster member publishes a captured experience to the subscribed thing-user according to its schedule.

The subscription request from a thing-user is reviewed and accepted based on evaluating the subscribing thing-user's social capital.

7.5 Thing-user manages the subscription and publishing of experiences in the level of cluster and each community tier — Finding the coordinated thing-user

The thing-user starts to search for a coordinated peer or peer group to help solve the problem of the thing-user by describing the problem statement. The measure of proximity to a coordinated peer is defined in the mission statement of the profile.

The thing-user checks the proximity to subscribed thing-users in the cluster. If the thing-user finds an appropriate peer thing-user, it requests for collaboration to solve a problem. If the thing-user receives the acceptance, the thing-user requests establishment of the proximal path to the coordinated thing-user.

If the thing-user fails to find a coordinated thing-user in the cluster, the thing-user starts to search for a peer over another cluster in the same level of community tier. If the thing-user fails to find a coordinated thing-user in the community tier, the thing-user attempts to search for a peer over clusters in the higher level of community tier until it finds a peer.

According to the mission statement, the proximal path will be established to either the single coordinated thing-user or the sequentially ordered coordinated thing-users.

7.6 Establishing and maintaining the proximal path

When the thing-user finds a thing-user or a thing-user group with which to coordinate accomplishing a mission collaboratively, the thing-user establishes proximal paths between coordinated peers depending on the type of collaboration group (peer-to-peer, peer-to-multi-peer, multi-peer-to-multi-peer) and the characteristics of collaborative communication.

The thing-user who makes a request to find a peer becomes the manager of the proximal paths between peers. The manager of the proximal path has responsibility for establishing, maintaining, and releasing the proximal paths.

NOTE The path for establishing over legacy networks is outside the scope of this document.

Annex A (informative)

FN-NoE thing-user centric communication service

A.1 Proximity defined networking procedure for thing-user centric communication service

A.1.1 General

Figure A.1 shows the procedure for coordinated networking among thing-users.

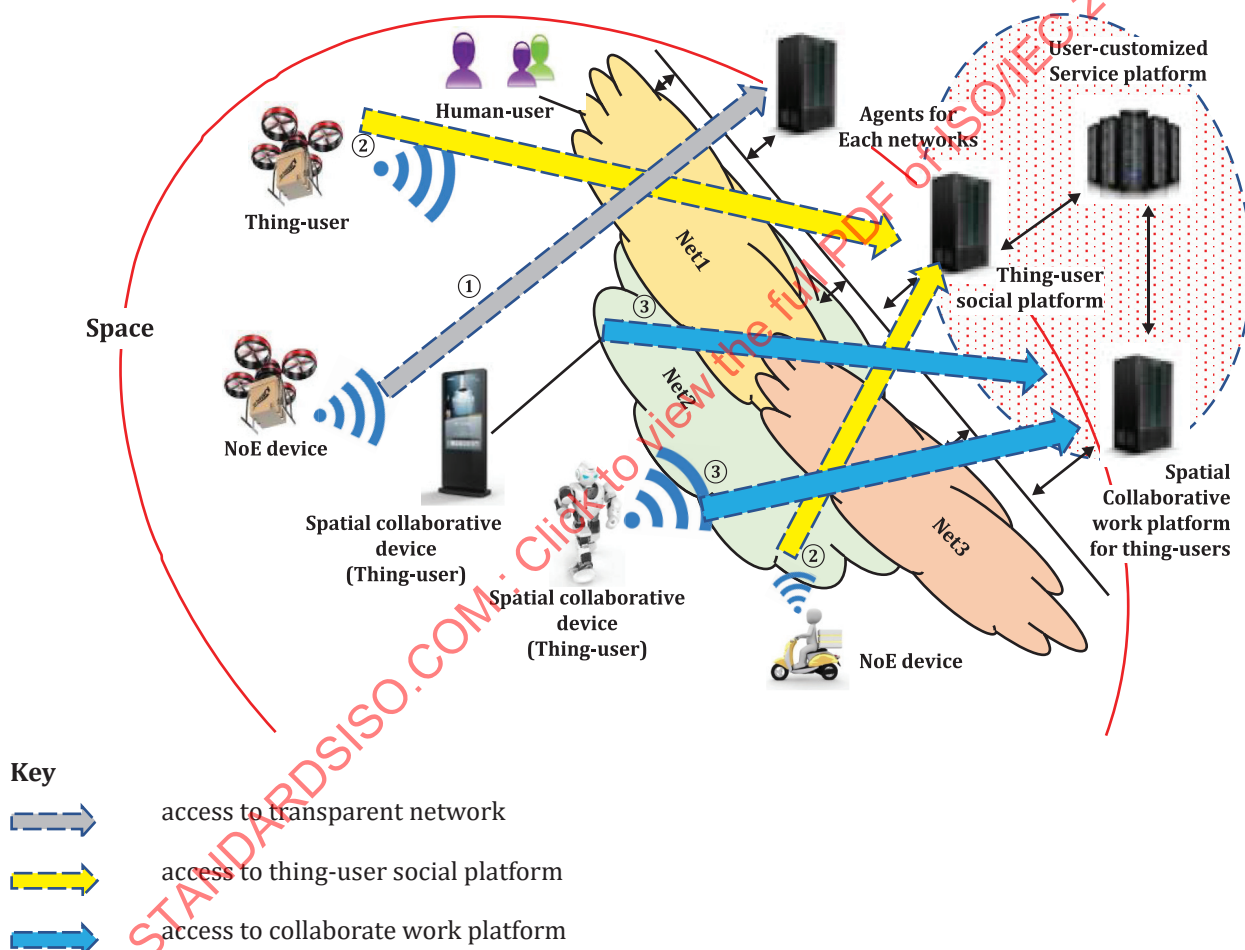


Figure A.1 — Thing-user coordinated networking procedures

A.1.2 Procedure for forming a thing-user social group

When an NoE terminal accesses a network through agents for networks (as noted as ① in Figure A.1), the NoE node can be a thing-user just after it joins the thing-user social platform through an appropriate authorization process (as noted as ② in Figure A.1). A thing-user social group will be generated by various online platforms, e.g. social platforms, specialized platforms (spatial collaborative work platform in Figure A.1), user-customized service platforms. Each platform can consist of various devices, e.g. servers, proxies, databases, virtual switches. The platforms for thing-user social groups