Analysis of Routing Protocols for Smart Community Networks

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●要約

スマートグリッドは、スマートコミュニティを確立するために適用する技術の一つです。スマートコミュニティにおける主要な技術要素は、通信及びネットワーク技術である。スマートコミュニティを確立するためには、安定的なネットワークとルーティングプロトコルが重要な役割を果たしている。本研究では、この業界で使用可能なプロトコルを調査し、最も適したプロトコルを取り上げる。加えて、SC のネットワークとして知られているスマートコミュニティ・ネットワークに展開するために、これらのプロトコルの特徴に関して研究を行う。

●キーワード

Route Discovery
AODV
RPL
Smart Community Networks

1. Introduction

1.1 Definition

Before delving into the definition of smart community, we are going to analyze how this term was introduced in the literature. We found that an electrical or power grid refers to all or part of an interconnected network for the transmission and/or distribution of electricity [1]. The traditionally operating grid connects suppliers of electricity with the consumers of it and the operation of which is largely depend upon the skills of power system operators. These skills are mostly associated with analog technology base.

As electricity supply and demand is necessary to keep in balance, grid infrastructure is built to deliver product without having proper storage system until date in most of the countries. However, in course of time, the demand of electric energy has been raised tremendously around the world. The increased amount of energy supply could not be sustained by the old infrastructure. In order to meet the increased demand of electricity, there were just few options. One of which is to supplement the high voltage power plant and replace the old infrastructure distribution of power line. In order to rebuild such kind of infrastructure there will be the economic burden not only for power suppliers but also for the country. On the other hand the problem of CO2 emission as a byproduct of power plant has been a headache from the early days. To address such issues the concept of incorporating some intelligent system in the grid has been attempted. The intelligent system utilizing ICT technology is thus emerged as newer technology in the industry of power engineering, energy industry and others in the name of smart grid. We will discuss the definition of smart grid followed by smart community in the following sections.

1.2 Proposed Concept of Smart Community

We envision the community who will be able to live useful lives thereby providing environment friendly and nature connected life. In order to perceive such kind of life we think that there should be harmonious relationship between community, human made infrastructures such as road, vehicles, railroads, buildings and surrounding natures. Therefore, our concept of smart community is that we learn from the nature and use our knowledge on behalf of nature and we utilize the nature in order to survive meaningful life. This concept is conceptualized as following points:

-Environment Friendly Community
-Environment Friendly Energy
-Environment Friendly Technology

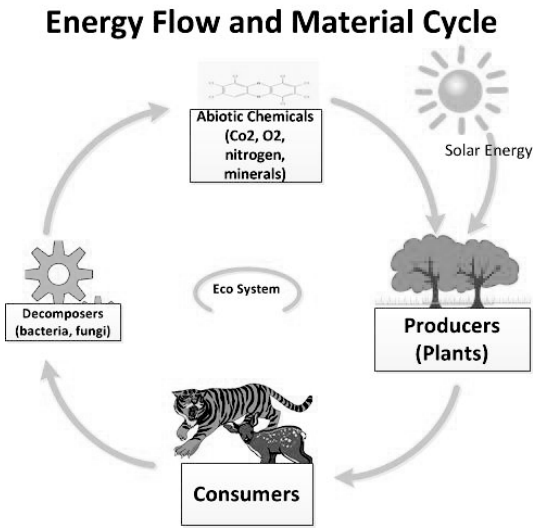

Fig 1: Energy Flow and Material Cycle

Furthermore, we view that in order to obtain sustainable system there should be an autonomous system which acquire the input and execute the output autonomously. In our concept, we observe such systems are autonomous in the nature.

As shown in figure 1, the biological system receive energy as light energy from sunlight which is transformed into chemical energy in organic molecules by cellular processes including photosynthesis and respiration, and ultimately is converted to heat energy. We gain heat energy that keeps up warm. This energy system is completed and remained balance if there are no any disturbing factors.

Similarly, we can utilize this eco-system of nature into our energy system. Obviously our source of energy is nature such as sunlight, wind, water and other natural resources. In the case of solar system, our source of energy is sun light; we capture sun light through solar panel that will change this energy to electric energy. In our scenario, we are relating these very balanced energy flows of nature into our renewable energy system. In this cycle, we have replaced the producer of plants to solar panel; we are adding storage module between producer and consumer.

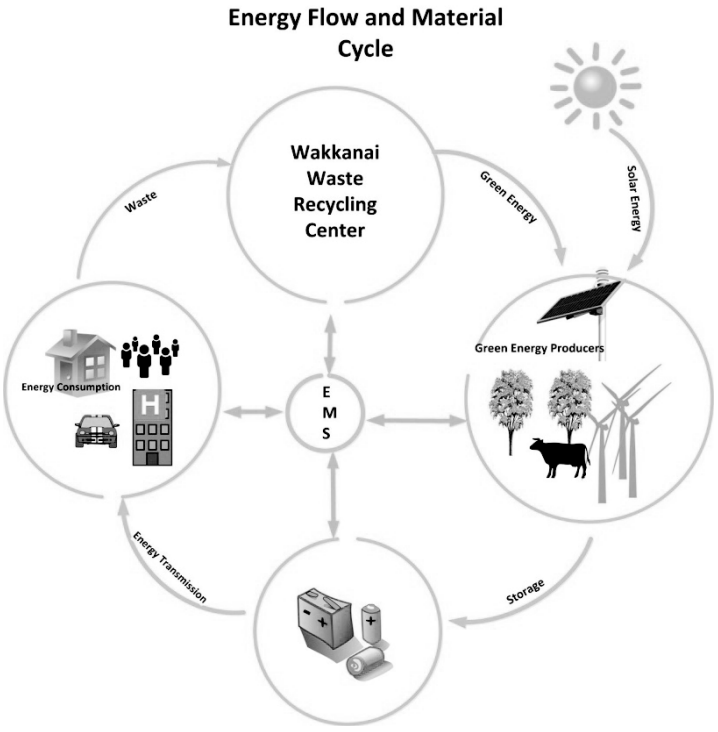

Fig 2: Energy Flow and Material Cycle

Thus, we observe nature, we learn from it and we take the reference form nature and we create the model technology in reference of nature in order to minimize the detrimental effect to it thereby making it an open system with respect to energy. Our philosophy is that as nature is open and as we are referencing our system from the nature, our system will be kept open to academic institutions, industries, researchers and other environment friendly group. This view of new energy system is based on the concept of ecosystem. We have learned this concept from the autonomous system of nature.

2． Energy Cycle in Smart Community

In ecology we have observed from early days that there is a fascinating energy factory system both exists in plant and animal. In term of animal life there is the use of tiny energy factories called mitochondira within the cells to handle the energy transformation processes necessary for life. In plants, the same kind of energy factories are performed by chloroplasts. They collect energy from the sun and use carbon dioxide and water in the process called photosynthesis to produce sugars. We can observe the energy cycle between plant, animals and energy source i.e sun in natural phenomena. We can analyze this cycle as energy producer, this role is played by sun, and the ATP of human cell can be taken as energy torage.

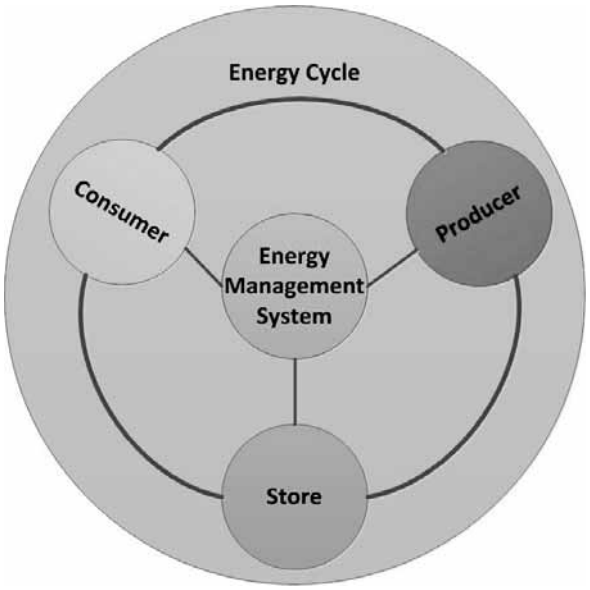

Fig 3: Energy Cycle

These natural phenomena can be applied in terms of smart community also. However, we need to take care of the balance of this cycle. We think without deploying green energy producers; it will be very difficult to balance this cycle. Additionally, without having proper energy management system, it will be difficult to have efficient utilization of energy.

3． Smart Grid and Smart Community

As we have mentioned above, Smart Grid technology [1], [7], [8] took a step after United States and many other countries put remarkable emphasis for modernization of the electric power grid. Japan has relatively better power grid however after the nuclear disaster it is becoming the central to national efforts to increase reliability and energy efficiency, transition to renewable sources of energy, reduce greenhouse gas emissions, and build a sustainable economy that ensures prosperity for future generations. So, what is Smart Grid technology and what makes the grid smart. Nowadays a huge amount of national budget is spent to build elements of what ultimately will be“ smart ”electric power grids. Bidirectional flows of energy and two-way communication and control capabilities will enable an array of new functionalities and applications that go well beyond“ smart ”meters for

homes and businesses Smart Grid provides sources of energy from suppliers to consumers which utilize ICT technology [1], [7], [8]. By using ICT technology, suppliers will be able to monitor the energy consumption scenario remotely. Furthermore, they will be able to monitor the increasing and decreasing rates of energy during peak energy use times. It is also beneficial to consumers that they will be able to monitor their energy use in real time, which could allow them to save money by conserving energy during peak energy use times [2]. This entry consists of total electricity generated annually plus imports and minus exports, expressed in kilowatt-hours. The discrepancy between the amount of electricity generated and/or imported and the amount consumed and/or exported is accounted for as loss in transmission and distribution.

As we mentioned above, smart grid is not a daytime invention, it is the technology which was emerged over time and the evolving process will continue in the future too. We believe that there are numerous factors that are contributing to affect this technology. Among those, one of the major contribution factors is renewable energy and ICT. We have realized that global warming is not only the issue of particular community and the country. It is the issue of the entire world. In order to decrease the CO2 emission, lots of countries are putting their attention toward renewable energy which is environment friendly. Furthermore, meeting the increased demand for renewable generation may require hundreds of thousands, or even millions of such generators, distributed across both the transmission and distribution networks. These generators may need to act together, effectively working as virtual power plants (VPPs), or may be located on every building across the grid, resulting in a distributed network of prosumers who both produce and consume electricity depending on their local requirements [2]. To summarize, smart grid is able to

- Detect and solve the potential problem before affecting whole network of the grid.
- Respond to local system after having the notification of disturbance in the grid.
- Manage self-healing system.
- Re-organize the energy flow with better routing algorithm, improve load patterns.
- Minimize the load shedding time during energy shortage.
- Enable local energy production thereby providing integration module in the main grid.
- Enable the design and operated with reliability and security as key factors.
- Provide visualizations tools in order to make efficient energy supply system
- Enable dynamic pricing

4. Routing Protocols and its Types

Routing is the process of finding the best path to the destination when packets have to travel from source to destination. Smart Community without a network infrastructure is not possible. And thus, they must be supported with stable networks. In a network, data communication is occurred through reliable routing protocols. Routing protocols are used in the legacy networks also. In this research, we were tasked to survey few protocols out of which we will be able to identify the suitable protocols for smart community networks. Routing protocols are mainly divided into two categories according to their behavior. They are proactive

protocols and reactive protocols

4.1 Reactive protocol

Reactive protocols discover routes whenever needed. Whenever route is needed to a source to transfer packets, source initiates the reactive routing. Therefore it has reduced routing overhead. No routing structure is created at the beginning. The advantages of reactive protocols are that it doesn't require periodic updates and is adaptive to network dynamics. Some examples of Reactive protocol are AODV, MANET etc.

4.2 Proactive protocol

Proactive protocols are short path protocols which are based on periodic updates. In this protocol all the nodes maintain the information of other nodes. Routing is based on periodic update information available with these nodes. Some examples of proactive protocols are RIP, BGP, and OSPF etc.

4.3 Hybrid protocol

The hybrid protocols combine features of proactive and reactive protocols. The network is divided into regions. The proactive routing protocol operates between nodes of a same zone whereas when the node has to send packets to node of other zones, reactive routing protocol operates between the zones. Some examples of hybrid routing protocols are dynamic zone topology routing protocol (DZTR) and zone routing protocol (ZRP).

Routing protocols are again classified into Distance-Vector routing protocol and Link-state routing protocol. It is based on the network information used in their algorithm to find the next hop node or communication link for routing the data packet to the destination in the most efficient manner. Distance vector routing protocol uses hop count to find the communication links whereas Link state routing protocol considers the network state of each link to decide the communication path.

5. Requirement of Smart Community network protocols

The requirements of smart utility networks have been defined in [RFC5826], [RFC5673], [RFC5867] which are home automation routing, industrial routing, urban routing, environment and in-building routing requirements respectively. The requirements are diverse as the smart utility network will be using wide range of devices and it should be compatible to all devices.

The nodes used in smart utility network will be low power devices with low data rate and low memory. The routing protocol will have to perform according to the need of the device. The most important of smart utility network is the inter-operability. All the devices and applications of smart utility network should adhere to interoperability standards specified by NIST in its Smart grid inter-operability model document [1].

6. Routing Protocols in Smart Community Networks

6.1 AODV

AODV is On Demand Distance Vector Routing (AODV) protocol which was developed initially for ad-hoc

network [3]. Ad-hoc network is the cooperative engagement of collection of mobile nodes without the required intervention of any centralized access point or existing infrastructure. The network will be able to dynamically self-start when AODV is used. As we know, in reactive routing protocol, source floods the route request packets when the route is required to reach the destination. Flood is propagated through network; a node passes the request only once. The destination replies to the request by using reverse route request path. In the following explanation we would like to elaborate how AODV works.

6.1.1 Route Discovery

The discovery process in AODV [5] begins with the creation of route discovery request packet known as RREQ message. This message is created in the source node. This packet contains the information of IP address and sequence number of source node and also the IP of destination's node and its sequence number. Initially,

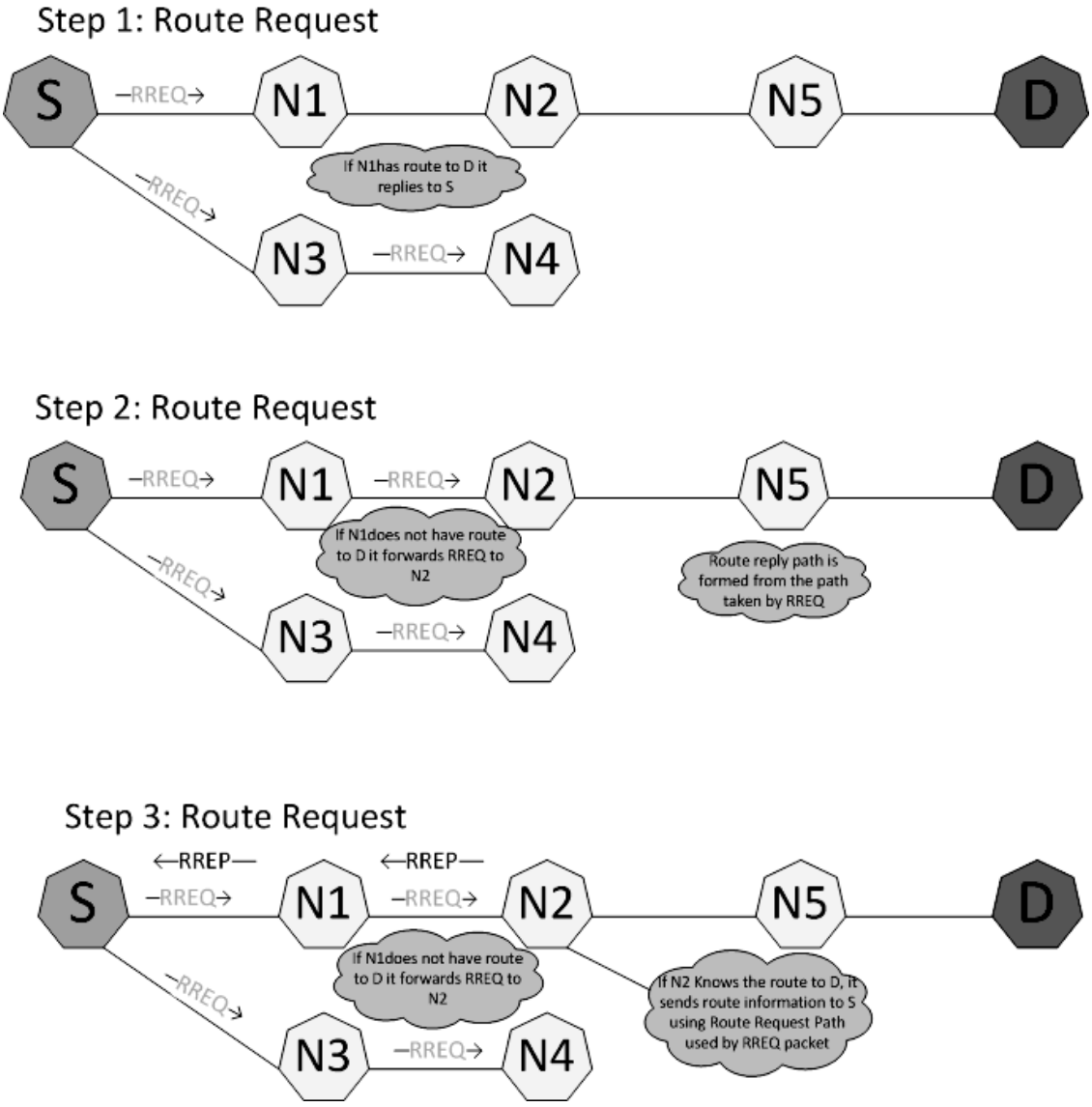

Fig 4: Route Discovery in AODV

while sending the packet to the destination, it looks the routing table of self, however, if it does not find its route in the table, it starts for route discovery.

The route discovery process starts from broadcasting the RREQ messages (as shown in figure no. 4) to its neighbours. If the neighbour nodes possess the route information of destination node, it will reply otherwise it will rebroadcast the RREQ message to its neighbouring nodes. In this way, the discovery process will be continued.

However, source node S will rebroadcast the RREQ message once the life span of its first packet expires and does not receive RREP message containng the route information of the destination node. Nonetheless, at this time the RREP will be send back by the process of unicast and no more floodings or broadcast is used. While sending back the RREP to the source node, the neigbouring node which has destination IP, will create the RREP message.

Finally, as shown in fig 4, node N2 will send back RREP message after creating this message which will contain the route information of destinate node D. In this way, route discovery will be completed.

6.1.2 Route Expiry

When the route is not used for given time, route will be truncated from the table. This is the main property of AODV protocol as this will reduce the maintenace cost also. Once the route is discarded from its routing information, this will be notified to its neighbouring node.

6.1.3 Sequence Number and Loop Avoidance

Sequence number plays an important role in AODV protocol in number of scenarios. The major role of sequence number can be realized during loop avoidance. As shown in fig 5, suppose that node S has the route information of node D initially.

However, let's assume that node S does not know that there was a link failure between node N3 and node D. This situation can be aroused while this information was lost. Now, let us say node N2 performs a route discovery of node D. After getting RREQ message by the node S, it will reply the route information via N2-N3-N4-S which will format the loop of N2-N3-N4-S-N1-N2. However, in AODV, this kind of loop will be prevented due to the concept of sequence number. The sequence number received by node S is lower than it originally has.

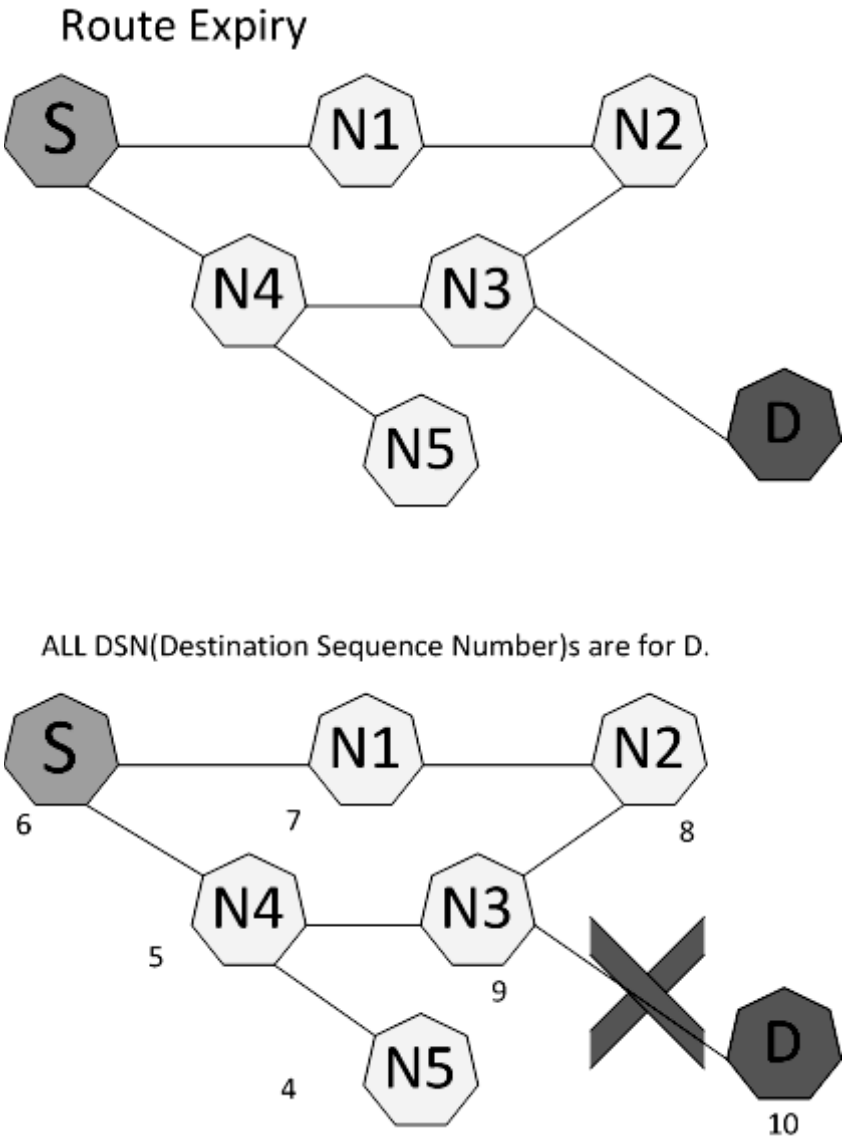

Fig 5: Loop Avoidance

6.2 AODV simulation using Omnet++

Omnet++ is a well-known discrete event based simulator built on C++ and NED. INETMANET is a framework built for OMNET++ that specifically simulates wireless ad-hoc networks. The installation guideline is described in appendix. We have simulated the network running AODV protocol using this simulator. We edit the default parameters of net80211_aodv sample. The network contains single fixed node into corner of the playground. Host 0 from the other corner initiates the communication to reach the fixed node using the randomly scattered nodes in the playground. The network parameters in omnet.ini files were set as following:

6.3 RPL

The Internet engineering task force (IETF) formed a group called ROLL in 2008 whose objective was to solve and survey routing issues of low power and lossy networks. The evaluation of seven existing routing protocols conducted by ROLL found they insufficiently meet the demands of LLNs. These protocols are those

```
##########################################################################
# manet routing
**.manetrouting.manetmanager.routingProtocol = "AODV"
##########################################################

# nic settings
**.wlan.mgmt.frameCapacity = 10
**.wlan.mac.maxQueueSize = 14
**.wlan.mac.rtsThresholdBytes = 3000B
**.wlan.mac.bitrate = 54Mbps
**.wlan.mac.basicBitrate = 6Mbps  # 24Mbps
**.wlan.mac.retryLimit = 7
**.wlan.mac.cwMinData = 31
**.wlan.mac.cwMinBroadcast = 31

# channel physical parameters
*.channelcontrol.pMax = 2.0mW

**.wlan.radio.transmitterPower=1.0mW
**.wlan.radio.bitrate=54Mbps
**.wlan.radio.sensitivity=-90dBm
**.wlan.radio.berTableFile="per_table_80211g_Trivellato.dat"


**.broadCastDelay=uniform(0s,0.005s)
```

Fig 6: Parameters values

Fig 7: Simulation of AODV using omnet++

specified in RFCs or a mature draft in development in an IETF working group. The new protocol developed called RPL which is still under continuous development. The detail analysis of the routing requirements focusing on several applications (Home automation, commercial building automation, industrial automation, urban environments has been specified by the ROLL group [4], [6].The protocol is designed for embedded applications which means it should support a variety of link layers which could be wireless or PLC (Power Line Communication). It also must work over ipv6 and 6LoWPAN.

The routing protocol: Ripple, RPL [4], [6] which is IPv6 routing protocol for low power and lossy networks consists of following features and entities:

Routing metrics: Computation of link and node properties

Objective functions: Selection criteria

6.4 6LOWPAN Routing

A Low power and LossyNetwork (LLN) consists of an edge router (also called as LLN Border Router, LBR), Router(R) and Host(H) nodes. Host chooses only a default router. Router forwards the traffic. ROLL only operates within LoWPAN and terminates at LBR.

6.5 LoWPAN routing requirements

There are certain considerations for routing over 6LoWPANs. Some of them are as follows:

ⅰ. The network should be optimized for Low-Power and lossy wireless technologies must be optimized for energy consumption

ⅱ. The devices used in the network consume low power and have less memory.

ⅲ. The data rate of such devices is very low and the specific data flow.

7. Future Works

In this research, we started to deepen our literature regarding smart community and the networks that support smart community networks. We have confirmed that we will be able to utilize the conventional routing protocols such as RIP, OSPF and BGP in our conventional networks and we can deploy relatively new protocols such as AODV and RPL in SC networks. We have analyzed AODV protocol as outlined in this research paper. The simulation of AODV was also done by using OMNET++. However, we were not able to utilize these protocols in real time environment. In our future work, we would like to try this protocol in real time environment and analyze the performance.

8. Conclusion

On a concluding note, the need for utilizing routing protocols as per the networks in smart community for sustainable routing mechanism that can be utilized for energy efficiency and monetary savings was revisited in this paper. As the smart community networks extends out to homes and businesses, wireless sensors and mobile control devices become important elements in monitoring and managing energy use. These nodes are comparatively new nodes of the networks and the routing protocols that would be applied in such kind of new networks should carefully be investigated. We have surveyed few protocols such as AODV, RPL and few other protocols in this research, the experiences of which can be utilized during the implementation of SC Networks.

● **References**

1. NIST Special Publication 1108R2, NIST Framework and Roadmap forSmart Grid InteroperabilityStandards,Release 2.0, URL: http://www.nist.gov/smartgrid/upload/NIST_Framework_Release_2-0_corr.pdf

2. Iain Morris, Japan's smart meter market opens doors to foreigners, URL: http://www.telecomengine.com/article/japans-smart-meter-market-opens-doors-foreigners

3. Ian D. Chakeres, AODV Routing Protocol Implementation Design, URL: http://moment.cs.ucsb.edu/pub/wwan_chakeres_i.pdf

4. Dr.-Ing. KoojanaKuladinithi, Wireless Sensor NetworksModule 2: Routing, ComNets, TZI, University of Bremen

5．Prashant Kumar Mauryaet.all, An Overview of AODV Routing Protocol URL: http://www.ijmer.com/papers/vol2_issue3/AC23728732.pdf
6．Dr. Baruch Awerbuch& Dr. Amitabh Mishra, Ad hoc On Demand Distance Vector (AODV) Routing Protocol, URL: http://www.cs.jhu.edu/~cs647/aodv.pdf
7．Yang Xiao, Communication and Networking in Smart Grids, CRC Press.
8．Lars T. Berger and Krzysztof Iniewski, Smart Grid Applications, Communications and Security

●英文要約

Smart Grid Technology is one of the emerging technologies that can be applied to establish smart community. The major technological segment in smart community is communication technology and networks. In order to support smart community through stable networks, routing protocols play a crucial role. In this research, we have surveyed a few available protocols in this industry and highlight the features of those protocols in order to identify best suitable protocols and to deploy them in appropriate networks such as Smart Community Networks known as SC Networks.