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MESSAGING ON SMART IOT MIDDLEWARE FOR SNOW MELTING ENVIRONMENT

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ABSTRACT

Abstract: Providing the safety on the roads on the most valuable task. It is time and money-consuming task on winter season to clean and melt iced and snowed roads. Currently, melting snow in roads use salt, that cause of corrosion infrastructure and vehicles, and elevated sodium levels in water. Putting heating cables or pipes are much better on this content, but energy consumption of this system very high since no accurate ice sensors, algorithms, and centralized real time control systems. On our research there built Snow Melting System for Smart residential districts. This system manages the iced road conditions, using installed sensors, forecasts and other road and weather related sources. On this research there were built IoT based Snow Melting environment, to research the environment there created local wireless sensors network on the 802.11n, also gateway built on Raspberry Pi, which operates group of nodes on the defined local area. Sensor nodes gather weather information such as air temperature, air humidity, ground temperature, ground humidity, wind, and send to middleware through gateways with MQTT protocol.

Keywords: *WSN(wireless sensors Network), Internet of Things, Snow melting, SOA(Service Oriented Architecture), Middleware*

1. INTRODUCTION

Sequence alignments are required to find the structural information on the proteins of unknown structure. If satisfactory multiple alignments are achieved for transmembrane (TM) proteins, we may predict the TM topology and the functional similarity of the proteins with some transmembrane segments (TMSs) [1]. Indeed, a few interesting methods for multiple alignment of TM protein sequences have been proposed [2, 3]. However, sufficient multiple alignment in a conventional manner is difficult most likely because of diversities of the sequences in data sets. Sequence alignments and their analyses are dependent on the pairwise sequence identity in the data set. The twilight zone of 20–35 % sequence identity has been discussed [4, 5].

The procedure of the treatment is developed using the pairwise sequence identities. Two new indices are introduced for the evaluation of multiple sequence alignments of TM proteins: the degree of TMS position diversity, *P*, and the degree of gap insertion into TMS, *G* [3].

The most effectual side of treatment lies in not including the diverse data sets. The collected data sets could be considered as beneficial as long as we have an appropriate limit value of sequence identity. To extract the structural characteristics of polytopic TM functional groups, the chosen sequences are needed to be valuable. Discussion includes the characteristics of our sequence selection treatment and consequent multiple alignments.

The Internet of Things is a modern model to connect smart embedded devices and systems over the network. That is to say, Wireless Sensor Networks gain popularity as an important substitute to create crucial systems such as industrial automation and distant patient monitoring.

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In this research there built Snow Melting System for Smart residential districts. This system charge of road iced conditions using installed sensors and other sources. Until now to melt snow in roads there were used salt that cause of corrosion infrastructure and vehicles, and elevated sodium levels in water. Using heating cables or pipes much better on this view, but energy consumption of this system very high since no accurate ice sensors, algorithms, and centralized real time control systems.

On this research there were built IoT based Snow Melting environment and this thesis focused to build the Middleware system for snow melting environment based on IOT also to melt snow from the road surface, to make roads safer and prevent accidents on the roads. This system uses high quality sensors, network and analysis system. To support the cooperation, these parts demanded middleware with minimum time consuming to set information from internal and external data sources, and exact decision algorithm.

However IoT is still-building technology there are variety kinds of standards and protocols. On this research used more common and high performance technologies. It helps to make this SOA IoT service more convenient to connect other IoT control systems.

To research the environment there built local wireless sensors network on the 802.11n. Also Gateway built on Raspberry Pi, which operates group of nodes on the defined local area. Sensor nodes gather weather information such as air temperature, ground temperature, ground humidity, air temperature, air humidity, wind, and send to middleware through gateways.

Among the middleware and sensor node built communication using the MQTT messaging protocol, which is, requires less energy and less network traffic however faster and have better QoS than other analogues. To store all data and logs from sensor nodes to process in real time and analyze in future there realized client for MQTT broker.

Upcoming chapters illustrates that improved middleware and system architectures, additional functions based on existing projects and implementing MQTT messaging protocol, android application for Snow Melting System on IoT environment.

2. RELATED WORKS

2.1 Snow Melting System by SH Korea

SH KOREA's snow melting system manages automatically by using thermal/humid sensor and it removes snow effectively. It has 3 layers of complete insulation and has strength to physical impact [6].

Using calcium chloride for snow melting can cause injury of road, corrosion of vehicle, contamination of trees and plants at nearby roads.

Electric heating system can be design and install easily to secure safety from heavy snow, frozen roads in winter time and has strength to mechanical impact and vibration. also it can be installed on all kinds of roof, gutter, waterspout golf course.

This system works in installed area without gathering data for analysis and users. Our system might be extended version of this work, combined with IoT technologies, data analysis servers and centralized control centers.

2.2 Monitoring and Control System by IoT

The IoT based water system is deployed using 2 different IoT sensors (i.e. ultrasonic, water sensor) by applying IEEE 802.11 communication standards. Integrating a wireless gateway within the consumer network does the data transmission of those sensors. Figure below shows the system diagram of the proposed system. A controller board based on the ATmega328P was deployed for the prototype design. The board consist of 14 digital I/O pins (of which 6 was used as PWM outputs), in addition with 6 analog inputs, a USB connection, and a power input source. In the proposed system, ultrasonic sensors are configured to determine the distance between the sensors and the water level in a tank [1].

The sensor emits waves and emitted data is displayed in LCD screens in centimeters. To manage the whole water monitoring system based on data analytics schema, a bespoke cloud server is integrated. Server stores all data coming from gateway and handles analytic related processes on these data. Also, server is meant to be used as a data store of information needed for web-based application. Timestamp is used to record the operations related to data collection while web-based application displays these data in a human readable format.

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	SH Korea's Snow Melting System	Snow Melting System based on basic IoT system	Our Snow Melting System
IoT devices	X	O	O
Big data analysis	X	X	O
Real time view	X	X	O
Energy consumption	O	O	O
Eco-friendly	O	X	O
Mobile application	X	X	O

Figure 1: Compression between existing projects.

3. SYSTEM BUILDING AND MIDDLEWARE STRUCTURE

3.1 Wireless Sensors Network Connection Structure and Management

Service computing or service science as a new research field has gained more and more attention. It has passed through two development stages [4].

With the rapid advancement of sensors and computing power of processors, there is a high demand in using dynamically distributed wireless sensor networks in different areas. Over the last few years, WSN technologies has been proven to be most beneficial way to control the systems of health, environmental monitoring, transportation, military applications, and many other fields.

A wireless smart network consisting of many sensor nodes will be dynamically distributed to different places working as a whole. It is likely that the network's arrangement architecture can not be predetermined. That is why, sensor nodes needs to be structured in ad hoc network architecture. It is ideal that the network be completely autonomous as to avoid any overhead and cost associated with direct human interaction. The crucial part of the network is the relaying of information to a central base station [7].

In 1996, Garter Group proposed the concept of SOA (Service Oriented Architecture) to speed up the creation of service-computing development. This was the initial high-tide of service computing.

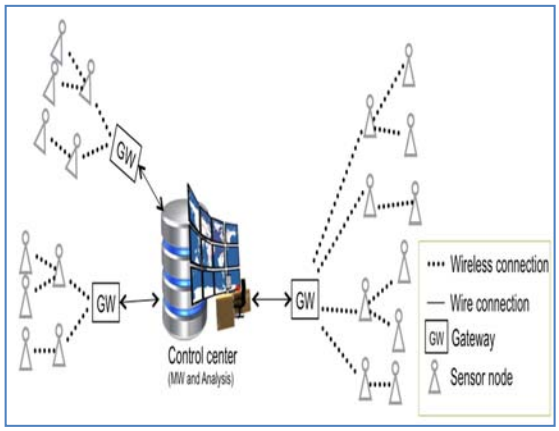

Figure 2: Network topology of IoT based Snow Melting Environment

Having all sensor nodes of the network directly connected to the base station is thought to be working in theory. But, because of the energy limits of single nodes, doing all operations in one place might not be that practical. Each ground sensors node controlled by Arduino connected to closer Air Sensors node by Bluetooth. Air sensors node controlled by Raspberry Pi gets data from ground sensors node and add air sensors data and IR camera data then send to middleware through the local gateway using MQTT protocol.

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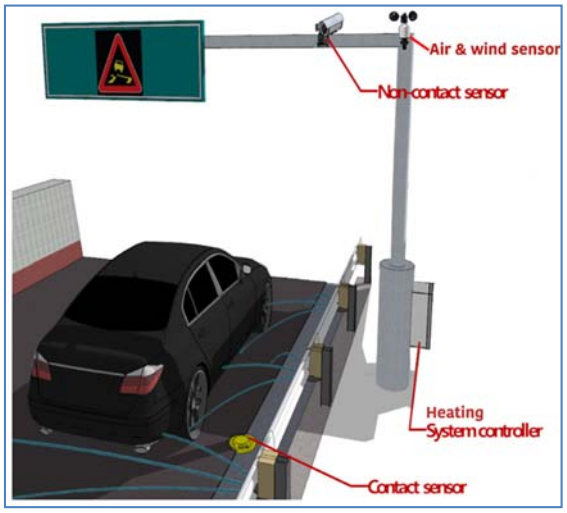

Figure 3: Sensor nodes installation

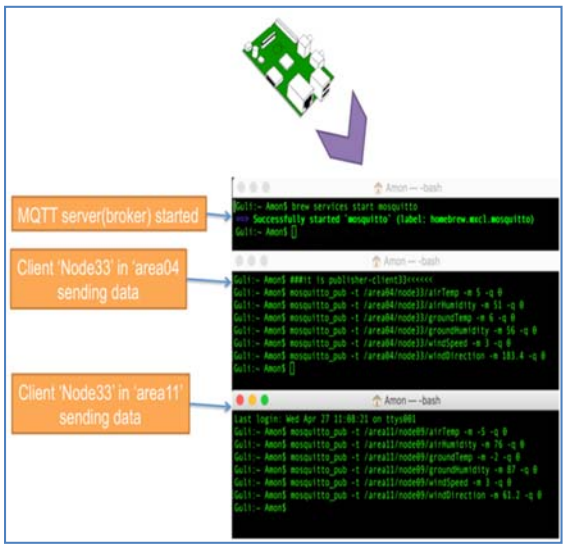

Figure 4: MQTT Message status from sensor nodes

Publisher clients send data using these topics:

- /<areaID>/<nodeID>/<SensorDataType>/
- /area01/node01/airTemp
- /area01/node01/airHumidity
- /area01/node01/groundTemp
- /area01/node01/groundHumidity
- /area01/node01/windSpeed
- /area01/node01/cameraImg

On the middleware to view messages in real time there used MQTT.fx. It is open source software compatible with all MQTT brokers, but only uses to seeing the messages, not for store, save or other functionalities.

Some of tasks run on middleware, such as real time weather events detecting algorithms on 'real time heating controller' but main of them runs on analysis server.

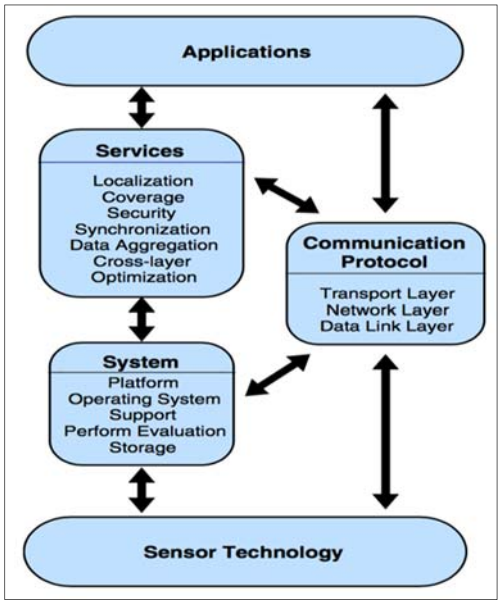

Figure 5: WSN various issues broad classification

3.2 Middleware Architecture by Snow-melting System

In IOT based snow-melting environment for restricted district area middleware connected in middle of the system and middleware manager with each layer of system by specialized modules [6]. To build it project divided to the four steps – four research parts, with every part worked different teams. Each step's task is clarified, and all connections unified in middleware.

All steps structured and modified based on existing architectures, which are recommended by IoT experts. The main key is middleware supplies several functions among the other steps. It helps to create communications between other steps in the IoT based Snow Melting environment.

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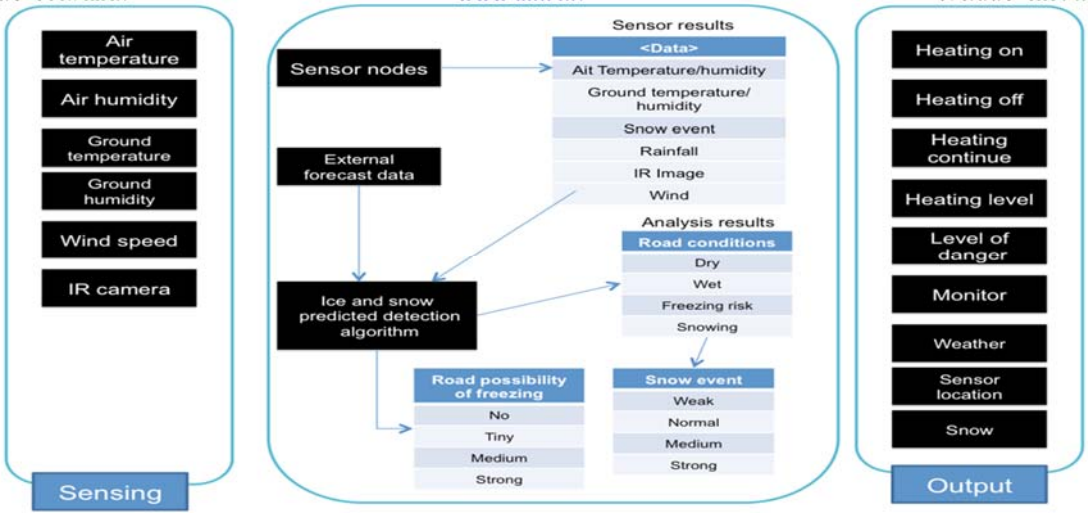

Figure 6: Snow operational procedure

First step – Legacy Step, gathers the data through internal sources, such as sensor nodes and external sources, such as weather forecasts, road accident, road construction and other road related open data sources. Second step – Middleware, has a communication interfaces with each steps and middleware is second built step among others.

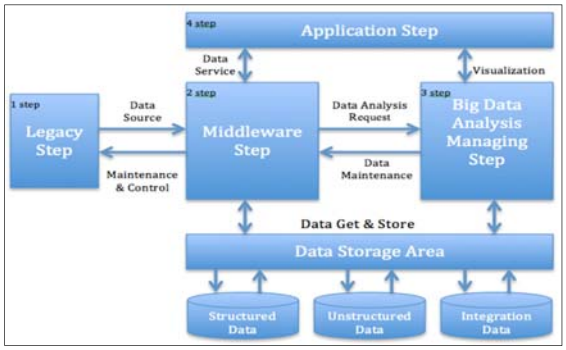

Figure 7: Four-step operation architecture of snow melting system

Third step – Big data analysis managing step, works with gathered structured and unstructured data, makes monitoring and forecasts. Fourth step – Application step, last, highest layer and important part, which is interface to communicate with users. Application step provides open API for web, PC and mobile clients, as a first example we developed android mobile application.

In the Figure below illustrated modules of middleware that manages with all the layers of the snow melting environment (Figure 8).

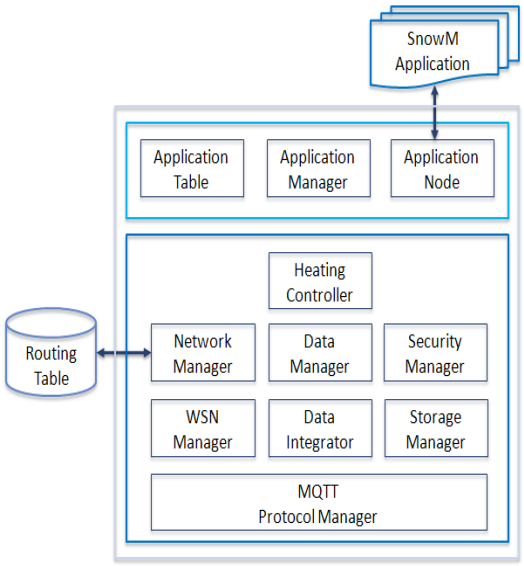

Figure 8: Construction of Optimal Smart Middleware System on the Snow Melting

From hardware and network layer to application layer there were build special software and protocols to provide flexibility and adaptability. Each module works autonomously and doesn't disturb others, instead these modules notify central control software if there exception for each other. Below key elements of them:

Routing table is a set of information which includes optimal route path to transmit packet to middle and server side.

Routing table includes the following information:

1) Destination: Final destination's IP address where packet needs to be sent.

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2) Next hop: IP address where packet needs to be received.
3) Interface: device that needs to be used when sending out the packet to the next hop or final destination.
4) Metric: Marks each available route with costs so that the most effective route path could be found
5) Routes: Contains subnets (directly-connected), indirect (not directly connected, but could be accessed through one or more hops) and default routes to use for specific types of traffic or when there is no sufficient amount of information.

Heating Controller – Controls the heating pads status according 'Ice event prediction', 'Snow event prediction' and 'Wet event prediction' algorithms. This module gets all the weather information from Nodes as a weather status subscriber on the MQTT broker and sends the commands to nodes to execute as a publisher [8].

MQTT Protocol Manager – it is add-on part of Mosquitto MQTT broker, which increases security on TCP/IP layer and unbox messages coming from sensor nodes and converts controlling commands to MQTT messages.

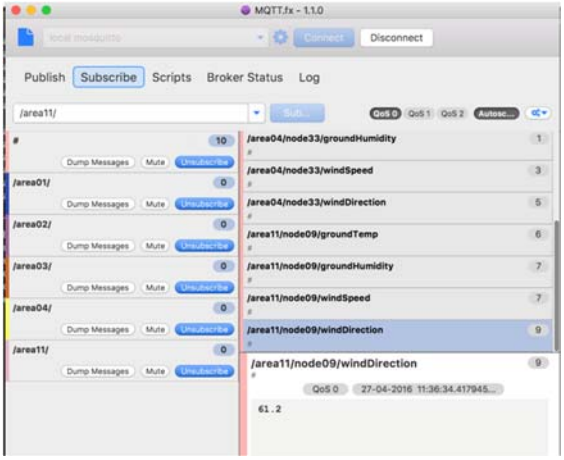

Figure 9: MQTT Message Monitoring Environment

Network Manager with Energy Manager – works as a part of WSN manager, gathers energy consumption, network resource consumption statistics which afterwards WSN manager can detect weak points.

In ideal case, the sensor nodes would remain in a dynamic environment until data collection and data analysis are done. However, it is unavoidable that in the working hours of the network, there happens a situation when some subset of nodes starts depleting their source of energy. The under the hood software of the network must be robust enough to handle these small changes in the network's topology. But, the long period of working time of each node results in the collection of better data in overall.

Data manager – subscriber of MQTT broker for all data and logs and stores all these data to database for future analysis. Talking from the perspective of a provider of M2M services (which you are when you are hosting your own broker e.g. for home automation or your applications), you typically have additional needs to generate added value for yourself or your customer. So let's say you want to store all MQTT publishes which are broadcasted to the broker for later analysis in a SQL database. In the easy words Data Manager is subscribed to a topic: /area/*/messages. Sensor nodes send message to Broker. Create a client in DB server which can subscribe to topic: /area/*/messages. Now, all messages between sensor nodes and Data Manager, will reach to the client as well, and we can store those messages in database. To make that there used Java programming language and Java Paho library to get access Mosquitto broker. Java Paho in open souce library built by Eclipse developers. Java Pahohere is if there is only client subscribe to a wildcard topic then it wouldn't scale well, will either need to distribute the load with sub topics among multiple clients or push the messages to a queue and have separate workers to pick the messages from queue and store to database.

Data Integrator – prepares gathered sensor node data for analysis server. In other words convertor that converts structured data to big data structure.

Security manager – provide security keys for MQTT message sharing structure every fixed amount of time. This technology used in Amazon Web Services, it generates 64-byte key for every client in network.

3.3 Android IoT Control Application

Middleware worked with static IP and connected to the internet and completely support other MQTT devices if connect them any time, only thing devices must have are account with password and security key, furthermore middleware asks device's IMEI and network connection parameters such as connected AP SSID, SSID password, network mask and store them on DB for security and to automatically establish of connection.

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Construction gives its' logs and outputs to MW and android IoT control application for customers (users). Android application shows all the sensors outputs and analysis outputs. Also allows control Snow Melting Environment manually if user has such privileges.

Application for user-administrator and user-moderator is same in the design, contains same configurations and parameters. Core of application contains MW data receiver and GCM manager mainly (Figure 10).

Mobile application is most important part of IOT project as far as it is end-point and controlling point of the system. All functionalities of applications divide to these modules.

Main View illustrates:

-Link to Map View, Link to analyze outputs

-Weather temperature, Wind speed, Humidity, Wind and Humidity changes graph

If user switches to Map View there might be seen picked area of user, weather stations and heating cable on it.

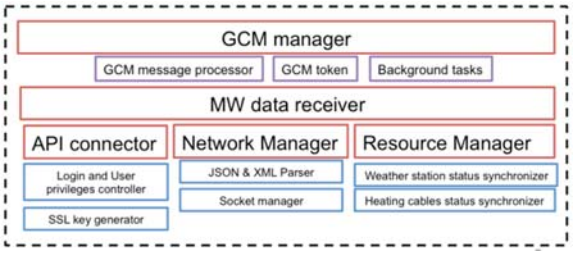

Figure 10: IoT mobile application Structure

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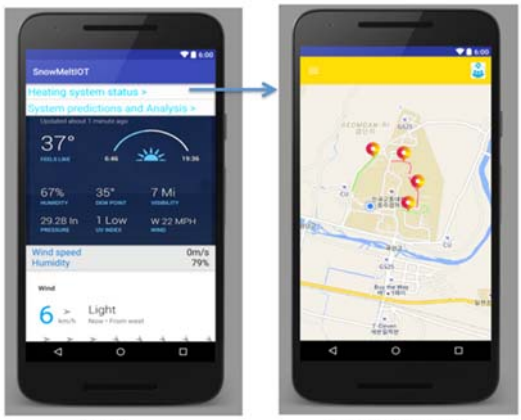

Figure 11: IoT mobile application views. a) Main View b) MapView

Mobile application is most important part of IOT project as far as it is end-point and controlling point of the system. All functionalities of applications divide to these modules.

-Main View illustrates:
-Link to Map View
-Link to Analyze outputs
-Weather temperature
-Wind speed
-Humidity
-Wind and Humidity changes graph

If user switches to Map View there might be seen picked area of user, weather stations and heating cable on it. Turned on heating cables can be seen easily, they ater in red color lines on the map, turned off cable parts are in green color. By clicking to weather station icon can be seen extended information (Figure 11 b).

3.4 Weather Detecting Algorithm

Middleware worked with static IP and connected to the internet and completely support other MQTT devices if connect them any time, only thing devices must have are account with password and security key, furthermore middleware asks device's IMEI and network connection parameters such as connected AP SSID, SSID password, network mask and store them on database for security and to automatically establish of connection.

The snow melting system has control middleware and big data platform to support integrated sensor node and camera.

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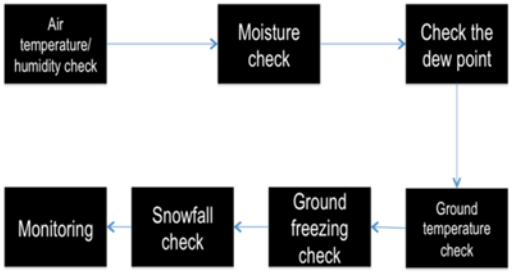

Figure 12: Operation steps to detect weather events

IoT based Snow Melting Environment with WSN's main task is to save electricity. For that purpose system required advanced formula to turn on/off heating cables. It cannot be based just on asphalt surface temperature or snow status on surface.

After many researches based on another algorithms there built algorithm to auto control heating cables based on:

1) Surface temperature
2) Air temperature
3) Surface humidity
4) Air humidity
5) IR camera outputs
6) Wind speed

There detected every weather events according sensor nodes data and data source from other public data. According the events status and heating cables status there generates commands to:

1) Turn on heating cables
2) Determine heating temperature
3) Determine elector intensity to get required temperature
4) Turn off heating cables

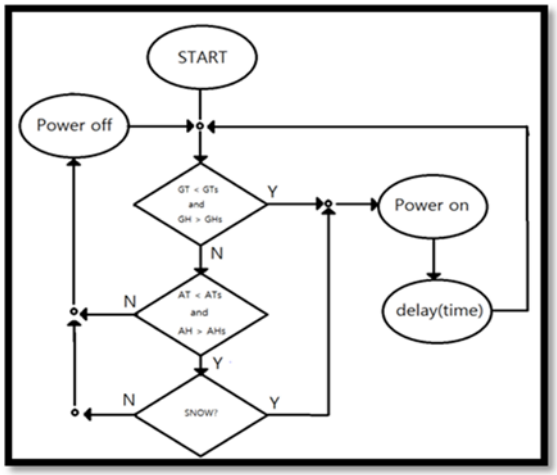

Figure 13: Power on/off for heating algorithm

Service computing or service science as a new research field has gained more and more attention. It has passed through two development stages [4].

4. RESULTS AND DISCUSSIONS

In this research, there built Snow Melting System for safe districts. This system charge of road iced conditions using installed sensors and middleware. The energy consumption of traditional system has inaccurate ice sensors data, algorithms, and centralized real time control systems.

On this research we are also offered the method of building Middleware and supports new features and IoT requirements. Our middleware system has allows work autonomously from IoT melting services for another IoT controlling systems.

As part of our future works are improving middleware architecture by adding new functionality and implementing machine learning to middleware. Additionally, supporting secure communication MQTT clients and brokers using advanced security protocols. We will make the prediction methods by improving big data analyses and composed of web application.

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