Abstract

The water supply block system is used for detecting a leakage by grouping the drainpipe network in large, medium and small blocks, and managing the maintenance of suitable fluid pressure and flow and measuring the flow of each block. As the block system of water supply was introduced, an enormous amount of flow data stream is created from the block, and the necessity to process this in real time has ensued. To resolve this necessity, this thesis reviews the method for detecting a leakage in the block in real time, using CEP (Complex Event Processing). CEP processes the events arising from multiple sources in real time, and derives a significant event. CEP is used to detect the occurrence of a leakage within the block, while observing the flow data obtained from customers in small blocks as well as the flow data of small block flow meters. Furthermore, this thesis presents the visualization tools for displaying the leakage results detected from CEP on the map.

Keywords: Block System, CEP (Complex Event Processing), Leakage Detection, Remote Reading

1. Introduction

To manage the flow and flow pressure effectively, the Korean water supply pipe network is structured as a block system. The block system is the management system of pipe network by grouping it into unit areas in large, middle, and small size. According to 2013 water supply statistics announcement by the Ministry of Environment, about more than 70% of the domestic pipe network structure is constituted as a block system.

The leakage quantity in 2012 was 626 million tons incurring KRW 510 billion, so leakage detection suitable for the block system is required to reduce these losses. Also as the water supply pipe network of the block system is very long, and the block system is established on the existing water supply pipe network, there are many old pipes so leakage shall be incessantly detected and repaired. Once leakage occurs losses continue as water escapes the pipe, so it is a very important issue how quickly leakage is detected and repaired. To respond to this issue, studies are underway to collect flow data and detect leakage through a remote reading system. However, the methods to detect the leakage from the block using the existing remote reading system does not consider the characteristics of the flow data collected from the block. The flow data collected through the remote reading system has the characteristics of data stream, occurring continuously and having time sequence. Also in order to detect leakage from flow data stream in the smart water meter belonging to a small block, and the flow data stream of the block flow meter, the function to handle complex processing between flow data streams is required.

CEP (Complex Event Processing) is the engine for carrying out complex processing of the stream data incoming from multiple event sources in real time. CEP does not store the data collected in real time, but performs processing on memory in real time, using Sliding Window. In addition, as CEP supports the complex processing of correlation or pattern etc. of the data arising from multiple event sources, CEP is suitable for water block system comprised of numerous smart water meters.

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This study presents the method to detect leakage occurring within a small block of block system in real time using CEP (Complex Event Processing).

The composition of this thesis is as follows; Chapter 2 gives the explanation on the block system and CEP. Chapter 3 provides explanation on the existing leakage detection techniques. Chapter 4 states the method to detect small block leakage through CEP. Chapter 5 performs the demonstration on the leakage detection by the proposed method. Lastly, Chapter 6 provides the conclusion and discussion in the direction of future studies.

2. Related Study

In this chapter, precedent studies regarding detecting leakage from block system are reviewed; detects with the method of analyzing minimum flow at night. The minimum flow at night means the flow coming into the block during 2 to 4 AM that is the night time slot with the lowest use of water. After measuring the minimum flow at night, in case leakage exceeds the allowable leakage standard, the relevant block is detected as leaking and leakage will be subsequently detected by personnel. The leakage detection method by minimum flow at night has limitations in that it detects leakage during night time only.

To resolve this issue, proposes the leakage detection method using the remote reading system. In this system, flow data from each water meter is collected into the data collector, and flow data is transmitted through the data collector to the server at a remote location. The transmitted data is stored through the database. All flows from the subordinate pipes was summed up with the interval of 80 minutes, and then the difference with the sum of the meters at final upper level pipes was calculated. This method has limitations in that the leakage occurring during 80 minutes cannot be detected using the bulk processing method, and furthermore, this is not suitable to the domestic environment as this method is intended for tree-structured water supply pipe networks.

Established the remote reading system targeting block systems, in order to detect leakage in small blocks. The flow data is collected from the meters of all families in the block system, and the collected flow data is gathered from the server at a remote location. After all, the flow data is collected at a database, the server has calculated the sum every day. This study has limitations in that the leakage at each block cannot be discovered in real time because mass flow data is processed in bulk at the database.

3. Real Time Leakage Detection Method

The leakage detection method presented by this study is performed through the process shown in Figure 1. This method is composed of the following process: First, the manager defines the leakage pattern in advance and registers it on the CEP engine. Subsequently, flow data is collected in real time and delivered to the CEP engine. Then, leakage is detected and reported to the manager.

3.1 Collection of Flow Data

In order to collect the flow stream data created from the smart water meter in the CEP engine, the flow stream data needs to be converted into the form usable in the CEP engine. First, event type must be defined.

Figure 2 is the class for using the flow stream data in the CEP engine. SN is the serial number allocated to the meter, with the properties to differentiate each smart water meter. This is given by the manufacturer of the smart water meter. BN is the serial number of the small block defined within the water block system, and is used for the management of the blocks. In case the number of a small block is n, then numbers from 1 to n are allocated.
most of the difference is estimated as leakage. Small block must match the flow. If an identical value does not appear, then leakage is the biggest factor, and so the quantity of water consumed at the homes within the small block. The sum of usages by each customer within the block. The sum of usages by each customer within the small block. The sum of usages by each customer within the small block.

As shown at Figure 3, the water volume inflow through the main pipe is measured through the small block flow meter. And as smart water meters capable of remote reading are installed in small blocks, these measure the quantity of water consumed at the homes within the small block. The sum of usages by each customer within the small block must match the flow. If an identical value does not appear, then leakage is the biggest factor, and so most of the difference is estimated as leakage.

Figure 2. Flow data class diagram.

| WaterFlow |
| --- |
| +SN |
| +BN |
| +MS |
| +flow |
| +getSerialNumber() |
| +getBlockNumber() |
| +getFlow() |

Figure 3. Small block structure and leakage.

MS represents the type of smart water meter. When this means small block flow category, this will have the value of “M”, and the smart water meter will have the value of “S”. Flow is the flow measured through the smart water meter, and has the unit of Liter (L).

3.2 Definition and Registration of Leakage Pattern

As shown at Figure 3, the water volume inflow through the main pipe is measured through the small block flow meter. And as smart water meters capable of remote reading are installed in small blocks, these measure the quantity of water consumed at the homes within the small block. The sum of usages by each customer within the small block must match the flow. If an identical value does not appear, then leakage is the biggest factor, and so most of the difference is estimated as leakage.

The defined leakage pattern is prepared in EPL as the event technology language that the CEP engine can interpret. Table 1 is the table showing the leakage pattern prepared in EPL. To discover a leakage, 4 stages in total were used.

Table 1. EPL Statement for small block leakage detection

| Stage     | EPL statement |
|-----------|---------------|
| Division  | insert into MainMeter select BN, flow from WaterFlow where MS="M" insert into SubMeter select BN, flow from WaterFlow where MS="S" |
| Aggregation | insert into SubAggregation select BN, sum(flow) as sumflow from SubMeter group by BN |
| Join      | insert into Join select M.BN, (M.flow – S.sumflow) as difference from MainMeter as M Unidirectional, SubAggregation.win:keepall() as S Where M.BN=S.BN |
| Filtering | select BN, difference from Join where difference > 0 |

- At the division stage, after small block flow meters and home meters are divided by MS properties, home meters are collected by SubMeter event, and block flow meter is collected by Main Meter event.
- At the aggregation stage, after events (SubMeter) divided as home meters are grouped by Block Numbers (BN), sumflow of all flow of meters within identical group is calculated, and then event results are collected at SubAggregation events.
- Joining stage is the statement to calculate the difference in the sum of the small block flow meters and smart water meters comprising the relevant small block. In case the block number is identical in the event results of MainMeter event and SubAggregation event, then Join is implemented. And then the difference is calculated between the sumflow calculated by the flow of MainMeter and sum of the flow calculated per block. Here, unidirectional properties were applied to MainMeter event type, so that join would be implemented every time MainMeter event is collected. Due to the properties of Sliding Window, join is implemented.
every time two joining events are collected. As leakage difference shall be calculated based on the arrival point of the flow stream data of Main flow meter for leakage detection, unidirectional properties were used to prevent any unnecessary calculation.

- At filtering stage, only values of 0 or more are derived using where section on the result of the Join event. In case the difference is found as less than 0, this is not the case of leakage and is filtered out through the filtering process.

3.3 Leakage Detection and Output

In case flow stream data delivered from the pre-defined maximum quantity, block leakage detection pattern, and smart water meters are collected, the CEP engine performs real-time processing based on the registered EPL.

To explain the internal processing process of the CEP engine, an example is used. First, the real time leakage detection process comprised of water meters numbered from 1 to 200 and one block flow meter is implemented as shown in Figure 4. The y axis represents the flow data stream created through each water meter and block flow meter. The x axis is the treatment process in the CEP engine.

Division and Aggregation stage are performed immediately upon creation of flow data of a home water meter. Through the Division process, flow data from home water meter (S) and block flow meter (M) is divided. At Aggregation stage, flow data of home water meter performs aggregation in real time. After 200 water meters generate 1L type flow date, the sum is calculated as the total collected flow data.

Thereafter, immediately upon collection of flow data from the block flow meter, Join stage is performed. At Join stage, the difference between the collected block flow and quantity of water used is measured by the home water meter. If the difference no less than 0 is revealed through Filtering stage, then the result shall be finally notified to the listener.

Finally, in case a leakage event is sensed through a listener, the leakage result is transmitted to the visualization tools and the result is displayed on the administrator’s page. For this purpose, the database was established to store the information from each water meter and information flow data from the block flow meters, and this was composed to display the location on the map through a web based application. Figure 5 shows the shape of 2 hypothetical blocks display on a map. In case a leakage is detected, the leakage information is displayed on the relevant block.

4. Leakage Detection System Design and Realization

To test the proposed small block leakage detection method, the system in the following prototype is designed and realized. The structure of the realized system is shown in Figure 6.

When a flow data and leakage pattern is registered through the event and pattern registrar, the flow simulator

Figure 4. Leakage detection process at CEP engine.

Figure 5. Screen of visualization tool.
generates a registered flow data through the registrar and transmits the data to the CEP engine, and the leakage pattern is registered with the CEP engine. The CEP engine monitors the flow data received through the flow simulator, derives the leakage pattern, and then delivers it to the administrator through the visualization tool.

Separate servers were set up for the web application for the CEP engine and visualization. By this arrangement, even though corrections occur at the webpage, the CEP engine continues its operation and performs processing. Database is used for management of location information and meter information. For the database, NoSQL based Cassandra 2.0.9 is used. As the web application, Tomcat 7.0 version is used. Web server receives leakage result discovered through a listener at the CEP engine through the HTTP adapter. As HTTP requested parameter value, the number (BN) of block where leakage occurred, the estimated leakage, the date and time of leakage are delivered. Relevant parameter values are stored at the queue, and then the result is continuously displayed to the administrator’s page through SSE (Server Sent Event). SSE delivers unidirectional information from a server to a client upon single HTTP request. As HTTP connection is maintained until request is suspended, this is suitable for displaying information on a leakage occurring in real time.

From the leakage information collected through SSE, the database is referred through block number to derive the location information of the relevant block. The relevant location information is displayed on the screen using the world map API provided by the Ministry of Land and Transportation. As data concentration cannot be tested on an actual remote reading system, data similar to an actual situation is created based on the actual remote reading data in Danyang-Gun.

5. Simulation

Using the prototype system realized above, leakage detection is tested. The case of a leakage occurring at a small block and a case where there was no leakage are tested. For this purpose, a hypothetical block numbered 1 and 2, as well as 200 hypothetical meters were registered at each block in the database.

The block comprised of a blue line is block number 1, and the block composed with green line is block number 2. Block number 1 is the case of a leakage occurrence, with data created per 1L at a hypothetical home water meter, collecting 12290L from 200 hypothetical water meters in total. A hypothetical block flow meter read 13000L after collecting data from all home water meters.

Block number 2 is the case where there was no leakage, collecting 12290L from 200 hypothetical water meters in total. In addition, the hypothetical block flow meter collected 12290L.

The result is shown in Figure 7. The number 1 block revealed 910L as the difference between block flow (13000L) and total quantity used by households (12290L), and the leakage result is displayed on the block number 1 position on the map.

From the result from block number 2, the block flow (12290L) matches the total quantity used by households.

Figure 6. Structure of block leakage detection system.

Figure 7. Leakage detection result screen.
(12290L), so leakage is not detected and not marked on the map.

6. Conclusion

The leakage detection method for leakage occurring in the block system is proposed using CEP (Complex Event Processing). CEP is the technique for discovering complex event patterns occurring at a large scale information system. In this study, the CEP technique was used to discover the difference between the flow into households and flow into the block by computing in real time. By this method, leakage is determined at a block system composed of numberless meters in real time, enabling prompt response to a leakage. Future studies will simulate the suitable environment for an actual block system composed of numberless meters, performing the function assessment on the system's capacity to verify whether the targeted functional level can be satisfied.

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8. References

1. Yoon M, Lee C. Development and application of DMA monitoring system to reduce water losses in water supply network. Journal of the Korea Academia-Industrial Cooperation Society. 2010; 11:2989–98.
2. Ministry of Environment. Waterworks Statics; 2010.
3. David CL, Brian F. Complex event processing in distributed systems. Computer Systems Laboratory Technical Report CSL-TR-98-754. Stanford 28; 1998.
4. Lee D, Kim D, Kim J, Kim K. Estimation of background minimum night flows by metering water use in water distribution areas. Journal of Korean Society of Water and Wastewater. 2010; 24:495–508.
5. Hsia S-C, Hsu S-W, Chang Y-J. Remote monitoring and smart sensing for water meter system and leakage detection. Wireless Sensor Systems. 2012; 2(4):402–8
6. Ministry of Environment. Development of management techniques to prevent leaks and to monitor individual water use for block systems of water-supply networks; 2004.