The Development of an Integrated and Context-Aware WebGIS of Alerting Information

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Abstract: Natural disasters have been major threat to Taiwan and caused huge damages over the years. To promptly collect and convey alert messages to people threaten by disaster is thus a necessary mission to the government. Because alert messages are issued by different responsible agencies, users are forced to deal with heterogeneous format of information to establish a complete and comprehensive understanding. Meanwhile, the alert messages are time and location dependent, making it much more complicated to deal with. Efforts for standardizing the alerting messages have been conducted, for example, Common Alerting Protocol (CAP), Sensor Web Enablement (SWE), etc. This paper discusses the design of an integrated WebGIS system that interprets alert messages following different alert standards and conveys context-aware information according to users' changing status. The open and standardized framework provides additional advantages of simplifying the duties and actions of responsible agencies and creating a flexible, expandable and interoperable application infrastructure for the general public. With timely and standardized alert messages available, more lives can be saved and damages can be effectively reduced.

1. INTRODUCTION

Natural disasters are major threats to people living in Taiwan. Many people lost their lives due to a lack of timely notification about the coming threats. In 2009, 677 people died during Typhoon Morakot in Taiwan. At Hsiao-lin Village, 480 people buried alive by debris flow at night, but people living in neighboring village survived because of the early evacuation. Timely alert information definitely plays an important role in emergency situation. It notifies people about the coming threat and give guidance about how to response to the threat, for example, the evacuation decision of citizens living in a particular region due to flood caused by heavy rain. There is an old saying that goes, prevention is better than cure. Early alert messages gives people more time to protect themselves and reduce the loss of resources and money. Government agencies and non-government organizations have been working closely in emergency situations to convey alert messages and help people in needs. To deliver the right information to the right people at the right time should be always looked up to as the standard.

In the past, general public receive information about nature disaster mainly thru the broadcast of public media, e.g., television and radio. While it can continuously supply information about disaster information, timeliness and effectiveness are always major concerns. It is a powerful way to rapidly spread the news and update progress, but it often lacks the ability to quickly convey alerts of sudden and local threat to the people. The technology breakthrough in internet, mobile computing and telecommunication opens a brand new chapter for conveying alert messages. For instance, Google Crisis Map (https://google.org/crisismap/weather_and_events) is a worldwide service that gathers alert messages from responsible agencies and displays alert information in an integrated fashion. Users can easily inspect the types, positions, affected area and the predicted directions of the threat. By taking advantages of the internet, anyone who holds a device connecting to the internet can continuously monitor the updated threats. Furthermore, the map-enabled interface allow users to focus on threats in the neighboring area. While users in the past have to wait for the public media to broadcast updated news one item at a time, they now have the flexibility to quickly select the information they need. If the convey of alert messages can be further improved by introducing context-aware service, that is, alert messages are pushed to only the people who under the threat, then the timeliness and effectiveness issues can be readily resolved.

The issuing of alert information heavily relies on the millions of sensors all over the world to provide instantaneous observations. Because of the versatile technology and protocol proposed by different manufacturers, heterogeneous has been a challenge for sharing sensor information. Sensor web was developed to establish an infrastructure for finding, sharing and accessing the observations and sensors via different sources (Bröring, 2011). Sensor web is not only about making sensors connect to the web, the major challenge is how to successfully transfer and share sensor observation, sensor description and alert message, and build an infrastructure to integrate all these resource together to fulfill interoperability requirements. Standardization appears to be the best solution for the above challenges. Standards are documents with detailed technology specification to implement the consensus agreement reached by related domains. Different standards for alert information have been proposed over the years, e.g., Sensor Web Enablement (SWE) by the Open Geospatial Consortium (OGC) and Common Alerting Protocol (CAP) by the Advancing Open Standards for the Information Society (OASIS). Although both are standards, each standard has its own unique ways to encode alert information, users thus still need to face the heterogeneous issue. By arguing every alert message is important regardless of where it come from, we intend to examine the interoperable interpretation of alert messages following different standards and discuss how alert messages from different resources can be integrated together for context-aware use in this paper. The remaining of the paper is organized as follows: Section 2 introduces the alert messages of SWE and CAP. Section 3 discusses the common and essential characteristics of alert information and compare the design of SWE and CAP. Section 4 discusses the development of an integrated and context-aware WebGIS for alert information. Finally, section 5 concludes our major findings and discusses future research directions.

2. STANDARDS FOR ALERTING INFORMATION

The most important criteria for an alert message is its content must be transparently interpreted by the recipients, therefore, standardizing its content by an open data structure and allowing recipients to develop compliant mechanism is the easiest way for establishing interactions between organizations. This section summarizes the development of two well-adopted international standards for alert information, the Sensor Web Enablement from OGC and the Common Alerting Protocol from OASIS.

2.1 Sensor Web Enablement (SWE)

Sensor Web Enablement (SWE) focuses on developing standards to enable the discovery, exchange and processing of sensor observations as well as the tasking of sensor system. (Boots, 2006) The current architecture of SWE includes a series of specifications addressing the encoding of sensor description and sensor observations and the standardized interface for a variety of sensor-related web services. While each specification has its own design purpose, these specifications can work seamlessly in an integrated way to complete a given task. For example, European Commission adopts SWE architecture to develop an air pollution monitoring mechanism called Open architecture for Smart and Interoperable networks in Risk management based on In-situ Sensors (OSIRIS) (Jose Maria Martin Bobis, 2007).

The SWE architecture works on a service-oriented basis, where each service has its specific interface and the interaction between them has been defined by the specification. Sensor Observation Service (SOS) is a standardized interface allowing users to access sensor observation, whose response content is defined by the specification of Observation and Measurement (O&M) and Sensor Model Language (SensorML). O&M deals with the content of observation and measurements from a sensor; SensorML describes the sensor systems and processes used to generate observations and measurements. (Botts, 2006) Sensor Alerting Service (SAS) is developed for publishing and subscribing alerts from sensors. SAS includes seven operations that can be requested by a client, namely, GetCapabilities, Advertise, CancelAdvertisement, RenewAdvertisement, Subscribe, CancelSubscription and RenewSubscription. (Simonis, 2006). Figure1 shows the UML diagram of the SAS interface. The advertise operation allows service owners to actively advertise alert messages to intended clients. The subscribe operation, on the other hand, allows users to subscribe alerts they have interests. Both of them can be renewed or be cancelled. The alert message includes the time, the affected area and value of the measurement.

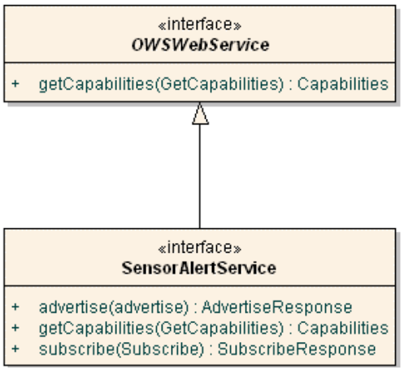

Figure 1 SAS interface UML diagram (Simonis, pp. 17)

When hazards strike, clients can continuously obtain updated sensor observation and sensor procedures from SOS. Once SAS determines the observation has exceeded the alerting threshold, alert messages are sent to the client in the subscription list. If necessary, users can send requests to the services and keep receiving upgraded progress of the alerts. Working on a standardized service basis, application developers can design their system via the open interface SWE provides. If all services are developed following SWE, the sharing of hazard information becomes much easier.

2.2 Common Alerting Protocol (CAP)

Common Alerting Protocol (CAP) is a standardized data format especially designed for exchanging emergency alerts. As a standard, CAP has been implemented in many public alerting systems and its message can be conveyed via different communication systems, such as radio, TV, web and cellular phones (Jacob Westfall, 2010) Canadian Association for Public Alerting and Notification (http://www.capan.ca/) operates a central alert aggregation system based on alert messages following the Canadian Profile of the Common Alerting Protocol (CAP-CP).

The major purpose of using CAP is to provide a standardized format of alert messages that can be commonly used by different system. Figure 2 shows the UML diagram of the CAP alert message, which is composed of four classes, namely, <alert>, <info>, <resources> and <area>. The class of <alert> is used to describe the identification information of the alert, including its message type, sender, time and status. Every message is given a unique ID for later management purpose. The class of <info> includes a series of elements to describe the details of the alerts, e.g. the time the alert becomes effective and expired, the type of alert, the level of severity and urgency, and most important, the introduction about how to react to the alert (e.g., evacuation). This class serves as a meaningful explanation of alerts and guidance for the general public to conduct appropriate actions. The class of < resource > provides links to additional reference related to what is recorded in the class of <info>. Finally, the class of < area > specifies the affected area for the alert message recorded in the class of <info>. The architecture of CAP is not designed for a specific type of alert, so each responsible agency needs to develop their own strategy about what information should be included. From a nation-level development perspective, a common specification all responsible agencies willing to follow is absolutely necessary.

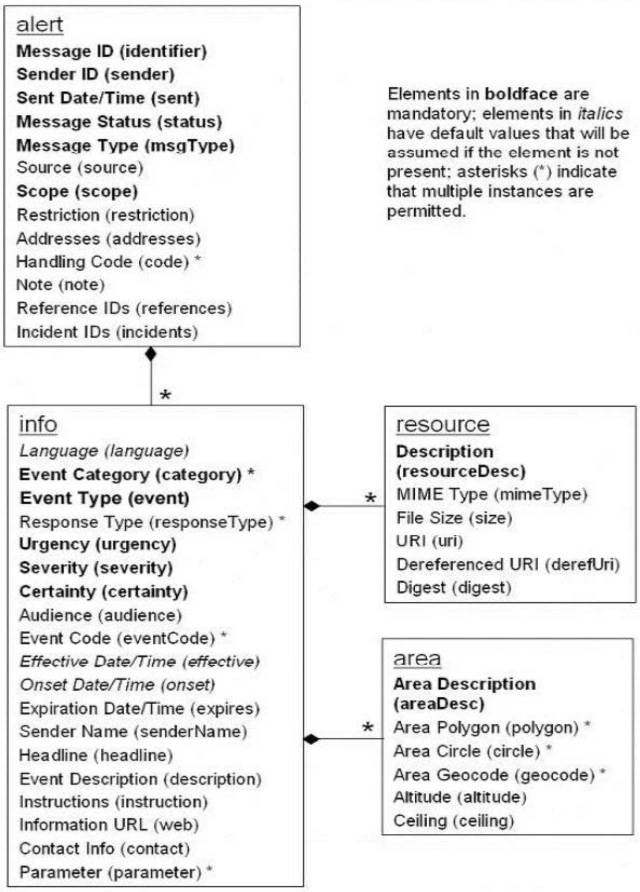

Figure 2 The Structure of the CAP Alerting Message (Westfall, 2010, pp. 12)

3. ESSENTIAL COMPONENT ANALYSIS OF ALERTING INFORMATION

Regardless what the standard or extended application profile is, we argue that every alert message must contain an essential set of elements for describing its common characteristics. Even different standards have their own schema and encoding rules, these essential elements still can be interpreted in an interoperable way by establishing mapping relationship between these standards. This section first analyzes the essential components, then use SWE and CAP as examples to compare their design strategies.

3.1 Essential components

The essential components represent the information that must be included in an alert message. Alert messages are issued by responsible agencies to give warning to people located at a specified region about when the threat begins, the influence it may bring and what actions the recipients should take. The discussion below follows the "5Ws and 1H" principle to examine the necessary information, e.g., what is the alert message is, where are the safe or dangerous places, when will the disaster happen, who publishes the alert, why this message is published, and how we should react to this alert messages.

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- What：The alert message should at least include information about the types and brief introduction of the alert. For example, the type of alert may include typhoon, earthquake, flood, etc. The content belong to this category must be readable by users.
- Where：If available, an alert message should specify the affected area of the alert. Any one who staying at the affected area will receive the alert message. As there are a variety of ways for describing the affected area (e.g., geographic names, polygons, circle, etc.), common specifications to enforce standardized recording are necessary. If the determination of affected area involves uncertainty, then the quality issue must be considered.
- When：The most important temporal information is when the alert message become effective and when it expires. This information determines the status of the alert message and help users to update the current situations. When an alert message expires, theoretically it should be removed from the platform. If the threat does not disappear, a new message must be issued to ensure the continuity of alert status. Every alert message has a published time, which is frequently used for tracking how long the message reaches its intended clients.
- Why：An alert message should explain why it is published. Too many alert messages simply annoy people and may on the contrary make them lose interests. The alert message is trigged because the risk analysis result has exceeded the predetermined threshold values. Using coding systems users familiar with can attract their attention, e.g., the scale of typhoon. The information about severity and urgency should be considered first.
- Who：This information specifies who publishes the alert messages and who should receive the messages. The sender normally refers to the responsible agencies, so that users know where they can look for further information. Different recepients may receive different messages (e.g., people living in different regions face different levels of threat), so it necessary to explicitly specify who shall read or react to the published alert messages.
- How：Alert messages are not only about notify that threat is coming, how people should react to the alert is also very important. The responsible agencies make suggestions according to their professional experience and knowledge, its content should take the scenario into consideration. For example, earthquake alert has less time to react, so the instruction should be as simple as possible.

The above analysis tries to summarize a list of essential components of alert messages, the results serve as the common foundation for alert information design. Before a cross-organization agreement can be established, different agencies may use different names for these elements and design more elements in their standards to address different application needs.

3.2 Alerting Information Analysis

This section examines how the above essential elements are defined in the respective standards of SWE and CAP. Since the two standards have their own schema, even the same element may be defined differently and cause interoperability problem. The following 7 items are chosen for comparison:

- Alert：In CAP, the elements of <headline>and <description> in the class of <info> provides human readable message for the alerts. SAS uses the element <ShortMessage> to record the alert information. Though defined differently, it is possible to extract a text-based description of alerts from both types of the messages.
- Observation Values and UOM：In SWE, the Observation & Measurement specification uses the a pair of elements, <name> and <value>, in <NamedValue> to record observations. SAS further includes a <isGreaterThan> element to record the threshold values for issuing alerts and < uom > to record the unit of measurement. Although CAP does not include specific elements for describing observations, such information can be either included in the <description> or defined by expanded elements using <parameter>.
- Severity and Certainty：In CAP, < severity > is classified according to the levels of alert and recorded by a predetermined codelist: “Extreme”, “Severe”, “Moderate”, “Minor” and “Unknown”. The element of <certainty> follows a similar design, which includes five codes: “Observed” (determined to have occurred or to be ongoing), “Likely” (>~50%), “Unlikely” (<=50%) and “Unknown”. Since CAP is already a standard, responsible agencies are required to map their own severity and certainty criterion to the corresponding codes. If responsible agencies have their own code systems, they can only use the element of <parameter> to define their systems. SWE does not have standardized code schema for the severity and certainty.
- Time：In CAP, time-related information in the class of <info> includes the elements of <effective>、<onset> and <expires>. The element of <effective> records the beginning time of the alert message, the element of <onset> record the expected time for the beginning of the alert and the element of <expires> records the time the alert message becomes invalid. All of these elements record the date and time using the data type of DateTime (e.g.”2009-07-31T15:12-07:00” for 15 July 2009 at 15:12 PDT). If the element of “expires” is not recorded, each recipient is free to set its own policy as to when the message is no longer effective. On the other hand, SAS provides the element of <TimeOfAlert> in sensor alert messages to record when the alert is triggered. The element of <DesiredPublicationExpiration > in Advertise operation defines the time the message will expire and <expires> in Subscribe operation defines the time that this subscription automatically terminates. All of types in SAS are recorded in the format of “YYYY-MMDDTHH-MM-SS+-hh:mm”. Though not exactly the same, the design principles of these two standards are very similar.
- Affected area：In CAP, the class of <area> is designed to record a region that will be influenced by the event listed in the alert. Several ways for defining the region are included. For examples, the polygon representation requires a minimum of 4 coordinate pairs (the first and last pairs of coordinates must be the same) to define a polygon. The circle representation is defined by two parameters: the coordinates of the central point and a

radius value. In SAS, <OperationArea> defines the area of operation of the sensor. The sub-element <GeoLocation> includes <lowerCorner> or <upperCorner> to record the <longitude>、<latitude> and <altitude>. All coordinates are referred to the WGS84 system.

- Instruction：In CAP, the element of <instruction> provides human readable instructions to suggest further actions. If different instructions are generated for different types of recipients, they should be recorded in different <info> blocks. SWE does not have similar design.
- Sender：In CAP, the class of <sender> defines rules to uniquely identify the sender of the alert message. SWE doesn't include sender informaiton.

Based on the above discussion, CAP obviously has a more complete schema of elements for describing the different aspects of alerts. Nevertheless, these two standards indeed share a set of similar elements for the essential components of alerts. Although they may be defined differently in the respective standards, a mapping relationship can be built by performing comparisons like we did in the above discussion. As long as the design principles for the corresponding elements are the same or transformable, we can successfully integrate alerts from different agencies together for users' reference.

4. WEBGIS SYSTEM ARCHITECTURE FOR ALERT INFORMATION

The proposed WebGIS system serves as a bridge between responsible agencies and the general public via the standardized alert messages. The general public can easily browse the alert messages in the map-based interface to establish an overall understanding. A context-aware system must further consider the content of pushed messages according to the place people is located. Since different types of alert messages may refer to different standards, the system also needs to have the ability to correctly interpret their contents. The first section introduces the basic workflow and the conceptual architecture of the proposed system. The second section demonstrates the experiment results.

4.1 Workflow and System Architecture

Figure 3 illustrates the basic workflow of the proposed system. First of all, individual responsible agency publishes alert messages in the standardized formats according the standard chosen. Once the web system receives the alert messages, the common elements discussed in section 3 are parsed and stored in the database. Note different standards may design different elements for describing the same alert information. If both the information of affected area and clients' location is available, the system automatically determines a set of alert messages that should be pushed to the clients. This can be easily completed by point-in-polygon test. If the affected area is specified by geographic names, then it should be transformed into corresponding polygons. Another possible scenario is when clients' location is specified by geographic names (e.g., street address), the decisions can be made by the textual comparisons of geographic names. Ideally speaking, the message will trigger certain effects (e.g., vibration, sounds, color changes, scrolling text marquee) on clients' devices to draw their attentions. As far as context-aware service is concerned, the selected alert messages are automatically pushed to the clients. Such ability allows the general public to receive alert messages in their nearby area without time delay. This is especially useful for emergency situations where people have to react immediately for the coming threats. What messages the clients receive will also depend on the devices and users' needs. For example, the alert messages may trigger alarm sound, such that people in the neighboring area can act accordingly without even knowing what the alert message is. For devices like scrolling text marquee, only portions of alert message content (e.g., the headline in CAP message) will be displayed.

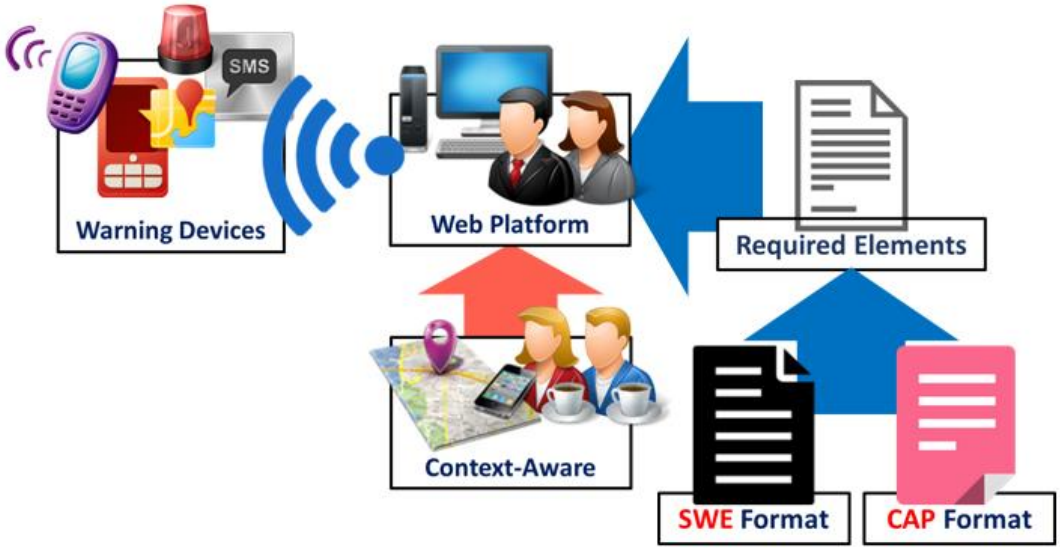

Figure 3 The architecture of the procedures of the web system

To continuously maintain a list of valid alert messages is very important to the proposed system. The following temporal information must be considered:

- The published time：This is the time when the alert message is published. Some alert messages become effective right after they are published, but some of them may be early warning. Therefore, the determination of valid alerts cannot be based on the published time only.
- The effective time：This is the time the information of alert message becomes effective. When the current time is equal to the effective time, the alert message is automatically added into the valid message list and analyzed to see if it should be pushed.
- The expired time：This is the time the alert message expires, meaning it should be removed from the valid message list. In push mode, a cancel message must be sent to recipients who receive the alert message before to notify the status changes. If the alert status ends earlier than the expired time, the corresponding alert messages should be removed immediately. On the other hand, if the alert status still persists, a new alert message must be issued to extend the continuity.

4.2 Prototype system implementation

The major objective or our experiment is to increase the interoperability of processing alert messages, so that it can be displayed and used in an integrated fashion even if the alert messages are referring to different standards.
Two types of alert messages of rainfall observations (established by SWE) and typhoon (established by CAP) are simulated. For simplicity reason, all the test data in this paper is simulated data and not real data. The system is implemented in ArcGIS Server 10. The test scenario assumes a typhoon is approaching and a rainfall station (depicted by red point symbol in figure 5) will continuously collect rainfall data. The threshold value is setup as when the 24 hour accumulated rainfall observation (Figure 4) exceeds 350mm, the alert message will be published.

Two persons living in different parts of Taiwan (depicted by blue star symbol in figure 5) are also simulated. Dependent on their location and the simulated alert messages, they may receive different messages at different time epochs. Since CAP and SWE have their own schema, this system needs to parse the required information from the two types of alert messages and automatically display the parsed results in the map interface. Two time epochs will be discussed in the following:

(1) At time epoch 1, the typhoon alert messages indicate most of the towns at the southern part of Taiwan (depicted by pink polygons) are already within its affected area; many towns northern of this region are not within the affected area (depicted by light-green polygons). Since both persons are within the affected area, they will receive the CAP-based typhoon alert messages (Figure 6) instructing them to stay at home and avoid going outside unless necessary. Figure 4 illustrates the simulated 24 hr accumulated rainfall data. When accumulated rainfall observation reaches 350mm at 02:57 pm on August 17, 2014, SAS is triggered to issue a SWE-based alert message. At this time, only the person within its affected area (depicted by blue circle symbol) will receive the alert message. Figure 7 shows the constraint of the "Subscribe" operation is setup as ">350" and Figure 8 shows the response results that indicates the time and the value of the accumulated rainfall.

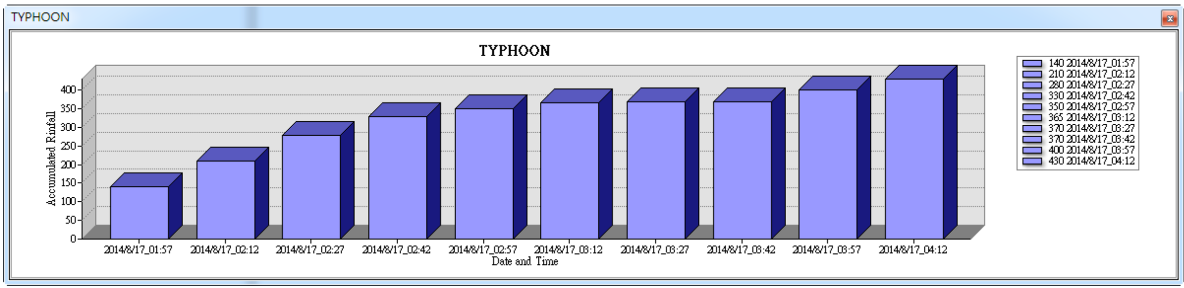

Figure 4 The graph of Accumulated Rainfall during Typhoon

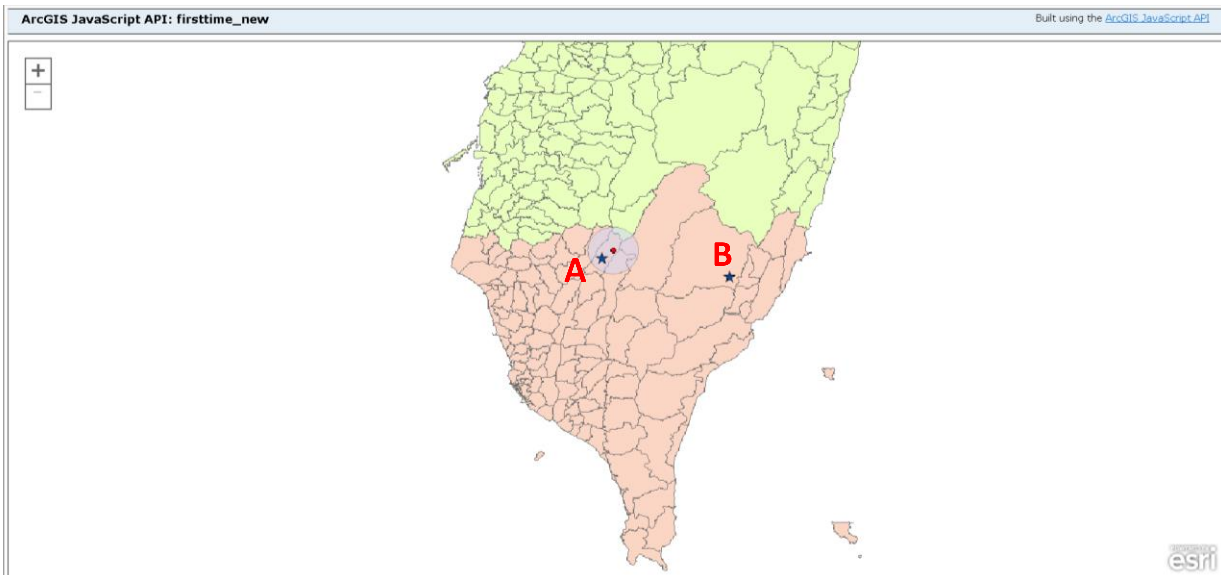

Figure 5 The affected area of typhoon and rainfall alerts at time epoch 1

```xml
<?xml version = "1.0" encoding = "UTF-8"?>
<alert xmlns = "urn:oasis:names:tc:emergency:cap:1.2">
    <identifier>igisrainfalltest1</identifier>
    <sender>IGIS LAB</sender>
    <sent>2014-08-17T14:57:00-08:00</sent>
    <status>Actual</status>
    <msgType>Alert</msgType>
    <scope>Public</scope>
    <info>
        <category>Met</category>
        <event>SEVERE TYPHOON</event>
        <responseType>Shelter</responseType>
        <urgency>Immediate</urgency>
        <severity>Severe</severity>
        <certainty>Observed</certainty>
        <expires>2014-08-17T16:00:00-08:00</expires>
        <senderName>Central Weather Bureau</senderName>
        <description>THE RADAR INDICATED A SEVERE TYPHOON OVER SOUTHEAST OF TAIWAN.</description>
        <instruction>TAKE COVER IN A SUBSTANTIAL SHELTER UNTIL THE TYPHOON PASSES.</instruction>
        <area>
            <areaDesc>IN SOUTH DISTIRCT OF TAIWAN</areaDesc>
            <polygon>23.0743,120.0236 23.4735,120.9486 23.1278,121.4178 21.9522,121.6069 21.8984,120.8520 23.0743,120.0236</polygon>
        </area>
    </info>
</alert>
```

Figure 6 CAP Alerting Message at time epoch 1

```xml
<?xml version="1.0" encoding="UTF-8"?>
<Subscribe xmlns="http://www.opengis.net/sas"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/sas ../sasAll.xsd"
service="SAS" version="1.0.0">
    <ResultFilter ObservedPropertyDefinition="urn:ogc:rainfall" uom="mm">
        <isGreaterThan>350</isGreaterThan>
    </ResultFilter>
    <FeatureOfInterestName>Taiwan</FeatureOfInterestName>
</Subscribe>
```

Figure 7 SWE SAS “Subscribe” operation for accumulated rainfall exceeds threshold

```xml
<om:OM_Observation
    gml:id="igisrainfalltest1"
    xmlns:om="http://www.opengis.net/om/2.0"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:xlink="http://www.w3.org/1999/xlink"
    xmlns:gml="http://www.opengis.net/gml/3.2"
    xsi:schemaLocation="http://www.opengis.net/om/2.0 http://schemas.opengis.net/om/2.0/observation.xsd">
    <gml:description>Observation test instance:severe rainfall</gml:description>
    <gml:name>Observation test 1</gml:name>
    <om:type xlink:href="http://www.opengis.net/def/observationType/OGC-OM/2.0/OM_Measurement"/>
    <om:phenomenonTime>
        <gml:TimeInstant
            gml:id="ot1t">
            <gml:timePosition>2014-08-17T14:57:00.00</gml:timePosition>
        </gml:TimeInstant>
    </om:phenomenonTime>
    <om:resultTime xlink:href="#ot1t"/>
    <!-- a notional URL identifying a procedure ... -->
    <om:procedure
    xlink:href="http://www.example.org/register/process/igisrainfall.xml"/>
    <!-- environmental conditions during measurement -->
    <om:parameter>
        <om:NamedValue>
            <om:name xlink:href="http://www.ncku.edu.tw/ontology/property.owl#Rainfall"/>
            <om:value xsi:type="gml:MeasureType" uom="mm">350</om:value>
        </om:NamedValue>
    </om:parameter>
    <!-- a notional URN identifying the observed property -->
    <om:observedProperty
```

Figure 8 The recorded value of the accumulated rainfall

(2) In the next day, as the typhoon moves, the towns in the eastern part of Taiwan are within the affected area, so the person living in eastern Taiwan receives an updated typhoon alert message, while the person living in southern Taiwan will not receive the message (Figure 9). However, because of the effect of southwest monsoon, the southern part of Taiwan is attacked by the extremely torrential rain. The 24 hour accumulated rainfall at the rainfall station again exceeds the threshold value and a rainfall alert is issued. At time epoch 2, the person living in southern Taiwan will only receive the rainfall alert message.

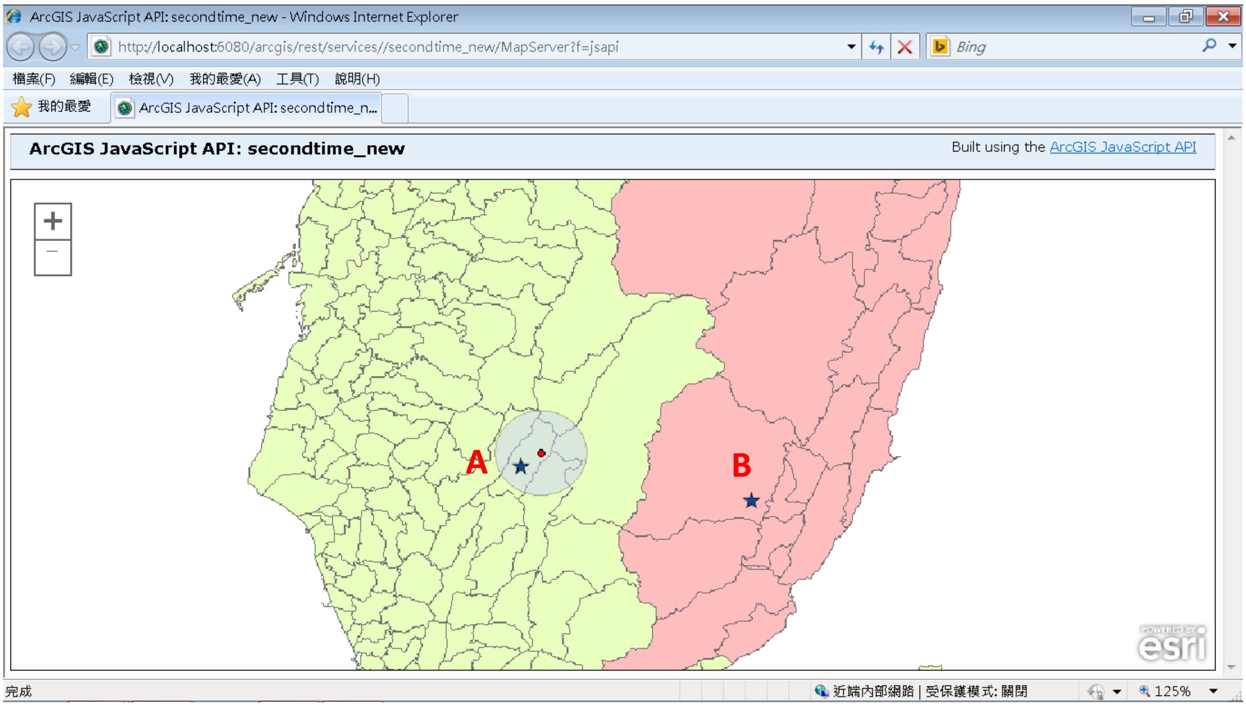

Figure 9 The Affected Area of Alert in CAP and Area of Rainfall Station at time epoch 2


```xml
<?xml version = "1.0" encoding = "UTF-8"?>
<alert xmlns = "urn:oasis:names:tc:emergency:cap:1.2">
    <identifier>igisrainfaltest2</identifier>
    <sender>IGIS LAB</sender>
    <sent>2014-08-18T14:57:00-08:00</sent>
    <status>Actual</status>
    <msgType>Alert</msgType>
    <scope>Public</scope>
    <info>
        <category>Met</category>
        <event>TYPHOON</event>
        <responseType>Shelter</responseType>
        <urgency>Immediate</urgency>
        <severity>MODERATE</severity>
        <certainty>Observed</certainty>
        <expires>2014-08-18T16:00:00-08:00</expires>
        <senderName>Central Weather Bureau</senderName>
        <description>THE RADAR INDICATED A STORM GETS SMALLER.</description>
        <instruction>THE TYPHOON IS SMALLER BUT SITLL SHOULD BE CAREFUL.</instruction>
        <area>
            <areaDesc>IN EAST DISTIRCT OF TAIWAN</areaDesc>
            <polygon>23.6513,120.7958 24.3365,120.9082 24.4435,121.3086 24.3163,121.7654 23.1278,121.4178 23.6505,120.8772</polygon>
        </area>
    </info>
</alert>
```


Figure 10 Typhoon alert eessage at time epoch 2

5. CONCLUSIONS

Alert messages play a critical role to reduce casualties and damages brought by natural disasters. The general public therefore should be constantly aware of any alert that may threat their lives and properties. This paper focuses on the interoperable interpretation of standardized alert messages and the development of context-aware service. By examining the essential elements of alert messages and the design strategies of SWE and CAP, we find most of the essential elements have been included. This enables the applications to aggregate and integrate alert messages published by different agencies together, even if these messages are originally referring to different standards. The context-aware service has the advantage of actively pushing messages to recipients according to their location. We successfully demonstrated the alert message mechanism can be operated on an interoperability and context-aware basis. This serves as the foundation for rapidly and effectively aggregating and distributing alert messages from different agencies to the general public. The success of such a mechanism, however, depends on the collaboration of responsible agencies, the development of nation-level aggregating systems and the ability for fast message transfer via a variety of communication technology.

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