Study on Location Trustiness based on Multimodal Information

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Abstract

Recently, location-based services (LBSs) have become popular and essential in many applications such as recommendation systems and disaster warning systems. The main challenge of the LBSs is obtaining the reliability of specified locations. In this paper, we propose methods to calculate trustiness of location based on multimodal information. First, we propose the equations for calculating trust value based on disaster information, which used a JSON web API to automatically obtain the earthquake information from United States Geological Survey (USGS). Second, we propose an approach to measure trustiness of a location based on collecting and analyzing sensor data. Furthermore, we present a combination approach for increasing the reliability of trustiness of location using both disaster information and sensor data. Our approach has investigated in making a geo-mapping matrix (GMM) which describes the impact of disaster events with the corresponding trusted value. To show the viability of our approach, we implemented a Java daemon program to collect disaster information, then calculate trustiness of location and apply to Software-Defined Networking (SDN).

***Keywords**: Trustiness of Location, Geographical Failure, Location-based, Sensor-based, Disaster Events, Multimodal Information*

I. Introduction

The trustiness of location is really important in location-based applications such as friends recommendations in social networks, disaster warning systems and network controllers. It enables the applications to be flexible in diffusing information. For example, when unexpected disasters such as earthquakes happen, the networks may get catastrophic impacts such as link failures. In this case, based on trustiness of location can help recover network links much switch.

There are several researchers who worked on trustworthiness of information. The dynamic source routing (DSR) is modified in [4] so that the path with the highest trust is selected among those leading to the desired destination, instead of selecting the shortest path, to enhance security. To apply for wireless sensor networks [2] focused on the way that trust information is combined with location-based routing protocols. [1] and [3] proposed the methods by using trust-based and location-based for social recommendation systems which predict the rating for user u on a nonrated item i or to generally recommend some items for the given user u based on the ratings that already exist.

In this paper, we propose two methods of calculating trustiness of location which describes the impact of natural disaster events on the location based on multimodal information. Our work makes the following contributions:

- First, we propose the equations for calculating trustiness of location based on earthquake information in which the data is collected from United States Geological Survey (USGS) in real-time manner.
- Second, we propose an approach for computing the trustiness of location by using sensor data. This work focuses on analyzing the output signals of disaster sensors such as smoke sensor and temperature sensor. Then, we calculate the impact of events based on feature data.
- Third, a combined approach using both disaster information and sensor data is presented, which put a weight factor on each kind of trust value.
- We also develop the algorithms for our approaches. An application model in network controller using trustiness of location is given. The results show that trustiness of location can be readily implemented and applied in real-life application.

The rest of this paper is organized as follows. Section II presents two main approaches of calculating trustiness of location: one is based on disaster information and another is based sensor data, and a combined approach of them. Section III implements the algorithms for our method, then evaluate the result. Finally, Section IV concludes the paper and discusses about the future work.

II. Calculating Trustiness of Location

A. Trustiness of Location Based on Disaster Information

In this section, we present an approach to computing trustiness of location using disaster events such as earthquakes. To do this, we define a geo-mapping matrix, then calculate the impact of an earthquake event based on the magnitude and location.

A GMM is defined by a matrix which covers the earth, the row indicates latitude from -90 degree to 90 degree and the column indicates longitude from -180 to +180. That is a set of locations L = $[L_{i,j}]_{n\times m}$, where $L_{i,j}$ is a location that shows starting position of each cell on matrix. A cell of this matrix has a size $c \times c$ with c can be a real number describing the length by kilometer.

We define a trustiness matrix T = $[T_{i,j}]_{n\times m}$ which describes the impact of earthquake events on matrix L, where $T_{i,j}$ denotes the trustiness of location for an earthquake event and $T_{i,j}$ is any real number ranging from 0 (no trust) to 1 (full trust). If the magnitude of earthquake $M \geq \rho$ with ρ is a threshold of the magnitude to set the trust value equals 0. The impact of earthquake e is described in a trustiness matrix $T^e = [T_{i,j}]_{K\times K}$, where K is the size of the matrix T^e and $T^e \subset T$.

Our approach for calculating trustiness of location based on earthquake information is as follows: (1) find a cell on the GMM where earthquake event e_i happened and (2) calculate trustiness of location around a cell, where e_i happened, including the previous events affected to the same cell on the GMM.

To find Possible Region Affected (PRA), we used an equation that is shown relationship between moment magnitude and surface rupture length of earthquake as follows [5]:

$$L_R = 10^{0.862069*M-4.37931} \quad (1)$$

where M is the magnitude ($M \geq 5.7$) and L_R is the surface rupture length of the earthquake. Thus, the size of T^e above is $K \times K$, with K is the minimum number of odd integer satisfying $K \geq \frac{L_R}{c}$. In our approach, the impact of an earthquake is decreasing linearly with the distance from epicenter to a location. We formulate the influence of an earthquake at each cell on T^e as follows:

$$T_i = \begin{cases} 1 - \dfrac{M}{\rho} & \text{if } i = 1 \\ T_{i-1} + \dfrac{M}{\rho * R} & \text{if } i \geq 1 \end{cases} \quad (2)$$

where i is a number of integer that shows the distance by cells from epicenter cell ($i = 1$) to R on the GMM, R is a number of integer and $R = \frac{K}{2} + 1$. To calculate trustiness of location at a specific location $L_{i,j}$ whenever an earthquake happens. Here, $L_{i,j}$ can be affected by a set of the earthquakes $e = \{e_1, e_2, .., e_n\}$ happened on the near $L_{i,j}$, where e_n is the nearest occurred event. Our approach based on averaging trustiness value of that cell on the matrix as follows:

$$T^n_{i,j} = \frac{1}{n}\sum_{k=1}^{n}(T^{k-1}_{i,j}) \quad (3)$$

where $T^n_{i,j}$ is the trustiness of location at $L_{i,j}$ after earthquake event e_n happened. By using an equivalent transformation, we have another equation for calculating trustiness of location at $L_{i,j}$ as the following:

$$T^n_{i,j} = \frac{n-1}{n}T^{n-1}_{i,j} + \frac{1}{n}t^n_{i,j} \quad (4)$$

where $t^n_{i,j}$ is the trustiness value at the location $L_{i,j}$ in the GMM, more details see in [5].

B. Trustiness of Location Base on Sensor Data

There are many kinds of sensors are used to detect disaster events that depend on certain characteristics of natural disasters. This section describes calculating trustiness of location using smoke sensor data and temperature sensor. Then, we present how to combine them to make the final trust value based on sensor data.

1) Smoke Sensor-based: In this section, we present an approach to calculate trustiness of location based on smoke sensors. The most sensor-based flame or smoke detection systems are based on infrared sensors, optical sensors, or ion sensors that depend on certain characteristics of flame and smoke. We choose optical sensors which use the effect of scattering and absorption of light by smoke particles to measure the amount of smoke. The intensity I_s of the scattered light depending on the incoming light can be described as follows [6]

$$I_s = I_0\frac{\lambda_1^2}{8\pi^2a^2}(i_1(\alpha, m, \Theta) + i_2(\alpha, m, \Theta)) \quad (5)$$

where I_0 is the intensity of the incoming light, λ_1 is the wavelength of the incoming light and a is the distance between the scattering particle and the light source. i_1 and i_2 are two intensity functions which depend on α the ratio between the particle radius and the wavelength of light, on m the complex refractive index and on Θ the scattering angle.

In our approach, we compute the trustiness of location based on the scattered intensity which is measured from the scattered light sensor. A threshold I_m that indicates the scattered intensity to alarming levels is used to calculate trustiness of location in smoke or flame situations. We formulate the calculating as follows:

$$T_{fir} = 1 - \frac{I_s}{I_m} \quad (6)$$

Using Equation 6 for calculating trust values from all the scattered light sensor data, we can obtain a trustiness of location by averaging those values, see in section II-C.

2) Temperature Sensor-based: In many cases, environment temperature not only affects human lives, but also effects on the performance of the systems. Therefore, we consider the environment temperature as a factor in calculating trustiness of location. There are many kinds of temperature sensors that can be used to measure the temperature, including: thermocouple, resistive, and thermistor temperature sensors. The analogue or digital signals of the sensors are converted to voltage signals into output, then send to the data center, subsequently calculate the impact of temperature and trustiness of location. The temperature value in Celsius (°C) is obtained by using a conversion equation voltage output based on the features of the sensor. For example, the TMP36 sensor provides a voltage output that is linearly proportional to the Celsius temperature, we can compute the temperature value by using the equation below:

$$T_{\circ C} = [V_{out} - 500]/10 \quad (7)$$

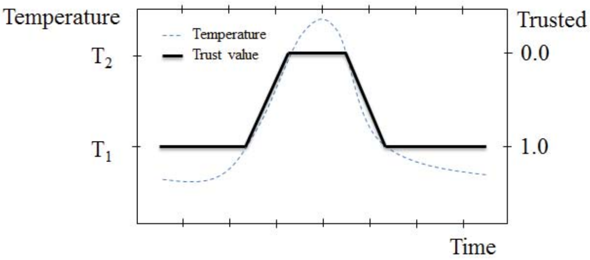

Fig. 1: An example illustrate the relationship between temperature and trust value

To measure the impact of temperature on that region, we define two threshold values: τ_1 is the maximum of temperature, which the system can still be working properly and τ_2 is the temperature value in which the system can not work, $0 \leq \tau_1 < \tau_2$. The relationship between temperature and trust value is illustrated in Figure 1. To calculate trustiness of location from the data that is provided by a temperature sensor, we propose an equation as follows:

$$T_{tem} = \begin{cases} 0 & \text{if } \tau_c \geqslant \tau_2 \\ 1 - \dfrac{\tau_c - \tau_1}{\tau_2} & \text{if } \tau_1 < \tau_c < \tau_2 \\ 1 & \text{if } 0 < \tau_c \leqslant \tau_1 \end{cases} \tag{8}$$

Averaging trust values, we can calculate trustiness of location by temperature for a region. In the next subsection, we show how this value is used.

3) A Sensor-based Model for Calculating Trustiness of Location: Figure 2 illustrates distribution sensors on the GMM. In this model, we assume several cells on the GMM used in some kinds of sensor such as temperature sensors and smoke sensors. Let $s = \{s_1, s_2, .., s_n\}$ is a set kind of sensor on a cell. Each kind of sensor is assigned with a weighting that indicates its degree of influence on trustiness of location. We define $w = \{w_1, w_2, .., w_n\}$ is a set of weight corresponding to s. For each s_i in a cell, we use m_i sensor(s). Let s_{ij} is the sensor jth in s_i, x_{ij} is trustiness of location from sensor s_{ij} which is calculated by using the equations above. We formulate for calculating trustiness of location based on sensor data as follows:

$$f_{(x)} = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{m_i}\sum_{j=1}^{m_i} w_i x_{ij} \tag{9}$$

Equation 9 is used to calculate trust value for each cell on the GMM in which exists at least one sensor. In fact, many cells where are not exist any sensor. Therefore, we define a factor for using trustiness of location with sensor-based method in calculating final trustiness of location (see the next section).

C. Combined Approach

This section shows an approach that combines trustiness of location based on both disaster information and sensor

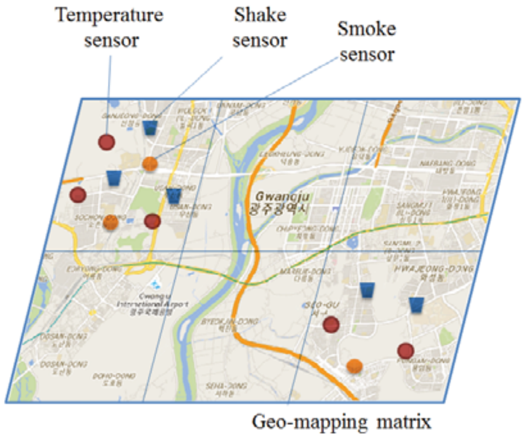

Fig. 2: A model distribution sensors on the geo-mapping matrix

approach. The trust value which obtains based on earthquake event is update to date every 5 minutes; meanwhile, using sensor data can be updated in a few seconds. Thus, the combination of these two approaches can make reliability the trustiness of location. To do this, we define T_D is the trustiness of location which is calculated based on disaster information such as earthquake events, T_S is the trustiness of location using sensor-based ($T_S = f_{(x)}$), see Equation 9. Now, the final trustiness of location T_L on a cell, at special time is defined as follows:

$$T_L = \omega_D T_D + \omega_S T_S \tag{10}$$

where ω_D is the weight for trustiness of location T_D, ω_S is the weight for T_S and $\omega_D + \omega_S = 1.0$. These weights indicate the degree impact of two kinds of trustiness of location in the same region (a single cell on the GMM). However, some cells are not exist any sensors, in that case, the final trustiness of location T_L equals T_D.

III. Implementation and Evaluation

To obtain the values of the trustiness of location, then apply to SDN controller, we propose a model as in Figure 3. This model depicts: (1) the input data is collected from three sources (a) the earthquake information from USGS, (b) the sensor data and (c) network infrastructure information that provide the location and link of network devices; (2) a trustiness of location framework that receives input data, calculate and responses the trustiness of location; and (3) control network flow by applying trustiness of location in routing.

Collection Earthquake Information

Java-based techniques are able to construct a program to automatically gather the earthquake information from the USGS site. We extracted the data with essential information including: magnitude, time, longitude and latitude. In this work, we perform the gathering in automatically by calling procedure *AutoCollection* as in Algorithm 1.

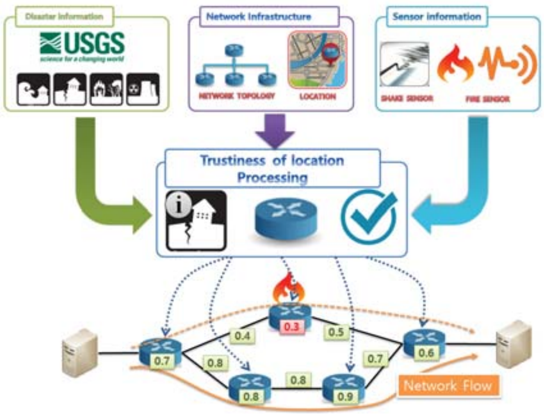

Fig. 3: Overall System Diagram

Procedure of Calculating Trustiness of Location

Algorithm 2 illustrates calculating trustiness of location based on earthquake information. In this procedure, we have shown the general operations in which the parameters are given, then call the procedure *GetValue* (not shown in this section) to get trust value for each cell on matrix trustiness of location.

Algorithm 1 Procedure ***AutoCollection*** is used to gather the earthquake information

Require: A path p is a JSON file that contains earthquake information
Ensure: A set of current earthquake events $E_c(id, m, t, lat, lon)$

$E_p \leftarrow \emptyset$; /* *a set of earthquake events*/
while (*true*) **do**
  $E_c \leftarrow$ ExtractJSON(p);
  for each event $e \in E_c$ **do**
    if $e \notin E_p$ **then**
      InsertToDB(e);
    end if
  end for
  $E_p \leftarrow E_c$; $E_c \leftarrow \emptyset$;
  Sleep(5*60000) /* *sleep 5 minutes* */
end while

Algorithm 2 Procedure ***CalculateTrustValue*** calculates trustiness of location based on earthquake information

Require: An earthquake event $e(M, lat, lon)$
Ensure: A matrix trustiness of location T_e

K← GetSizeOfMatrix(M);
T← new T[K][K];
for (i = 0; i ¡ K; i++ **do**
  for (j = 0; j ¡ K; j++ **do**
    $T[i][j] \leftarrow GetValue(i, j, e)$;
  end for
end for
return T;

Applying Trustiness of Location to SDN Controller

We consider the problem of calculating the trust value of a link L_i in the network topology. A link L_i in the network topology can be represented by a polyline. We treat a polyline as a single object, including component segments. Each line segment is identified by two points: source location and destination location. So, we can make the line y between two that points. Next, we consider the finding all cells in which the trustiness of location is less than 1.0 and the line y is crossing. Finally, the trust value of each link in the network topology is obtained by averaging the trustiness of location at the positions of that link affected by the disaster events.

To apply the trustiness of location in SDN controller, we implemented a module that calculates continuously and update the trust value of the links into the database. Then, we install a module in SDN controller that is used to monitor the trust value of each link in network topology. These values are used to change the routing table whenever a link affected by disaster events. In that case, a higher trusted value to be the priority instead of the shortest path.

IV. Conclusions and Future Work

Location-based systems have become popular and essential for various applications such as friends recommendations in social networks, disaster warning systems and network controllers. This paper presented the approaches to calculate trustiness of location based on disaster information and sensor data. Through the results of the initial implementation, we show the viability of our method.

In the future work, we plan to deeply consider the method for computing the trustiness of location more exactly. Besides that, we will find the applications to provide the services and applications based on this study.

Acknowledgments

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