An Architecture for IoT-Enabled Smart Transportation Security System: A Geospatial Approach

Jun Zhang, Yichuan Wang, Shuyang Li, Shuaiyi Shi

Abstract— **Internet of things (IoT) in urban transportation systems have been ubiquitously embedded into a variety of devices and transport entities. The IoT-enabled smart transportation system (STS) has thus gained growing tractions amongst scholars and practitioners. However, several IoT challenges in relation to cyber-physical security are exposed due to the heterogeneity, complexity and decentralization of the IoT network. There also exist geospatial security concerns with respect to the embeddings of 5G networks into public infrastructures that are interconnected with the transport system via IoT. To address these concerns, this paper aims to apply geospatial modelling approach to propose a Smart Transportation Security Systems (STSS). It is modelled and simulated by undertaking an experimental study in the city of Beijing, China. The simulation outcome of the proposed architecture is expected to offer a strategic guide for strategic security management of urban smart transportation.**

Index Terms—**5G, cyber-physical system, geospatial analysis, infrastructural designs, Internet of Things (IoT), security control, smart transportation systems (STS), standardization**

I. Introduction

A group of "things" embedded by software, electronics, actuators, sensors, which are linked through the web to gather and swap information with one another is termed as Internet of Things (IoT) [1]. As reported by the International Data Corporation (IDC), the rapid progression of the variety of IoT equipment used is forecasted to achieve 41 billion by 2020 with an $8.9 trillion market [2]. In particular, IoT has been deployed in the smart transportation systems (STS) that allows optimizing transportation resources and facilities and providing better traffic management to the citizens [3]. To date, there has been a plethora of IoT-enabled STS applications at scale. For example, heterogenous transport data sources are captured from millions of vehicles, thereby establishing a data-driven traffic network that is often termed as 'internet of vehicles' [4]. Driven by IoT, the STS recommendation system has developed on the basis of predictive computation of user behaviors [5] through initiatives like traffic control rooms and surveillance systems.

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Driven by IoT, smart transportation is increasingly advanced by, and embedded with, cyber-physical system (CPS) which is built on open network technologies and sensor networks that realize interconnections between different nodes of transport, instantiated as a system of systems [6][7][8][9]. However, such an IoT-driven, CPS-embedded smart transportation faces several challenges related to cybersecurity and 5g-enabled network connectivity, due to its heterogeneity, complexity and decentralization [4][5].

First, while using the IoT equipment in the smart transportation solution, a variety and large volume of data (e.g., traffic data and sensor data) are generated [5][6]. These data, if they are harnessed in a proper manner, could help monitor the physical traffic environments and achieve the smartness of the transportation system. However, with data explosion in the STS, traditional security schemes cannot be implemented on IoT environments because the nodes contain limited memory space that cannot manage the data processing and storage necessities of improved security procedures. Such data explosion issues also cause system cyber-insecurity due to potential data leakage and breach [10]. ***Second***, device-to-device contact permits the IoT nodes to swap data with one another in an independent manner. The successful utilization of the device-generated data improves the scheme execution by making valuable knowledge of the domain. However, swapping data between various IoT systems is a challenging task due to the heterogeneity, complexity and decentralization of IoT-enabled STS. ***Third***, the capacity and security of wireless network communication is of utmost importance for the STS due to real-time transport of IoT traffic and fast response requirements from smart applications. Current IoT-enabled smart transportation security system mostly suffers from low bandwidth and high communication cost [7]. Furthermore, the nodes of wireless network embedded in the STS may not be physically secured and exposed to unsafe conditions.

These challenges may not be overcome by simply utilizing existing solutions that are available for 'conventional' systems, namely, to addressing CPS related security problems. This is because CPS and IoT innovations are mainly concerned with data and smart devices, concentrating on micro-level information exchange and data transmissions across nodes [11][12][13]. Macro issues in relation to geospatial and public infrastructural configurations would also need to be set up, i.e. geographical indicators that impose large-scale influence on the deployment of transportation infrastructures and sensor networks. We claim that overcoming above challenges requires the combination of both cyber-physical security and geospatial security management. Therefore, this study proposes an IoT-enabled smart transportation security system (SSTS) that is aimed to address comprehensive security problems of city transportation. The main contributions of this study are three-fold. Firstly, we offer an overview and theoretical explanation towards the system architecture for the IoT-enabled STSS. Second, we bring together two disciplinaries of information science and geoinformatics, and integrate them as a solution to address transportation security concerns. Third, we employ an experimental study to investigate the city of Beijing to simulate possible performance for the application of STSS.

In the rest of this paper, we present a system architecture of STSS in Section II. The simulation of STSS application is presented in Section III, followed by a discussion of the interrelationships between layers and factors in the STSS architecture, and an overall planning strategy towards its effective deployment. Conclusions are drawn in the last section.

II. Architecture of STSS

The proposed architecture (Figure 1) of IoT-enabled STSS proposed in the paper is composed of three layers, including (1) security control mechanisms and standard systems, (2) a 5G-enabled remote communication network, and (3) public infrastructural design and geospatial parameters. The upper and intermediate layers are concerned with cyber-physical security whilst the lower layer stresses geospatial security management. The intermediate layer acts as the instrument through which IoT-enabled networks bridges the control and standard systems to public infrastructural and geospatial designs. The following sub-sections present the functionality and components of each layer.

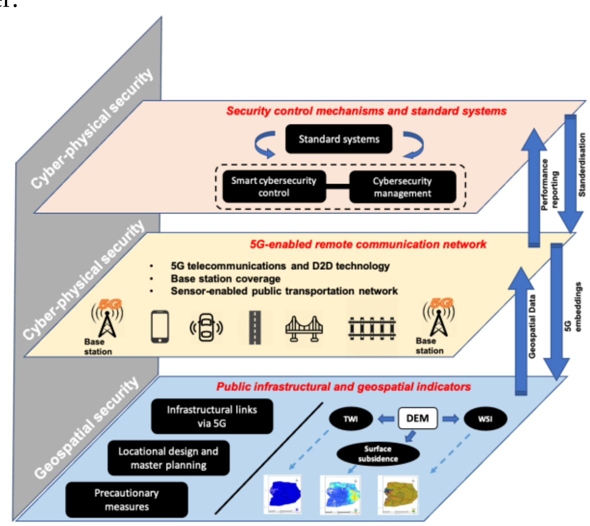

Fig. 1. The Architecture of STSS

A. *Security control mechanisms and standard systems*

Security control mechanisms and standard systems refer to a set of national and international data and system protocols rolled out by standard organizations and technology corporations, for the purpose of normalizing the design and implementation of intelligent systems, and verifying, validating and calibrating parameters of these systems [1][2][14]. For the STS, transport entities – e.g. bikes, cars, buses, trains, and undergrounds – are identified as the units of the CPS, and have been increasingly networked via IoT, i.e. 'internet of vehicles' [15]. CPS in this sense transforms how humans interact with real-world transportation scenarios [18], in a way that transport entities are equipped with sensors, navigation devices, and high-speed internet bandwidth. Instant messaging and telecommunications across these entities would enhance overall efficiency and effectiveness of the STS. However, given its instantaneity and high capacity nature [16], the CPS-enabled STS entails security protection systems to ensure persistent and stable data transmissions cross the entities. In what follows, three key components are presented in this layer: the smart control environment, STS cybersecurity management, and the construction of STS standards.

The *smart control environment* is concerned with the embeddings of sensors and actuators into transportation infrastructures (e.g. bridges, gas stations, medical services, car parks) and data processing systems (e.g. smart traffic light systems, traffic guiding systems, emergency systems, video vehicle detectors, city dashboards). These essentials are not simply defined as non-functional and technical requirements, but also entail functional, regulatory and legal procedures to monitor the overall efficacy and operationality of the pervasive sensor network and protect it from unintended attacks.

Cybersecurity management refers to the building of mechanisms to identify unintended risks of end-user services, including cyber-attacks, privacy violation and information disclosure. A typical effective mechanism is data sharing protocols for point-to-point transmission of STS data generated from both end-user devices and transport infrastructures. When data are transferred across sites of practice, it is necessary to identify security requirements which allow for the legitimacy of data being used and re-used, and for what purpose. These requirements are often specified through formulating cybersecurity policies and developing appropriate software and hardware tools [17].

Establishing STSS standards refer to an information security management system which provides overall strategic roadmaps for designing and implementing the STS. International standard-making organizations like IEEE and International Organization for Standardization (ISO) make specific data and system standards, requiring specific data structure, format and data sharing protocols [18]. Our proposed architecture in security control involves technical specifications on the basis of the standard for IoT-enabled smart city data transmissions across transport entities. Data generated from different nodes follow the same standard from the data acquisition process to the end-user service layer.

B. *5G-enabled remote communication network*

A 5G-enabled remote communication network allows faster timely communications across nodes of transport via internet. Vehicles, transport infrastructures, public transports and people's mobile devices become data points which continuously transmit information from one site to another [19]. 5G plays an important role in connecting the overall control mechanisms and standard systems on the first layer, and public infrastructures and geospatial indicators on the third layer. In comparison with previous generations of network technologies, 5G is featured by its high capacity, reliability, wide coverage, and energy efficiency [20]. This addresses the weaknesses from previous cellular standards and therefore further enables IoT deployment [21].

In transportation, 5G enabled remote communication networks can improve the efficiency of transportation security control. This is determined by whether the 5G base stations have the capacity to cover 5G data transmissions between infrastructures and transport entities via the D2D (device-to-device) technology. Whilst 5G is important to mobile transport through smartphones [22], it is also crucial to deploy transponders to the public transport network to realize instant communications between users and public transports. A proper system that supports just-in-time access to information from a distance away of public transport stations (e.g. bus stops, underground stations) without delay, needs to be set up [23]. Smooth transit of both vehicles and humans nearer to public transport stations is crucial to the convenience of transportation, which further indicates security and safety.

Based on the remote communication network enabled by 5G, real-time transport data within a certain area can be connected into a network as a whole. As such, certain practices of control for transport entities can be easily carried out (e.g. urban control rooms). This improves the regional response rate, reduce in accidents and optimize the security control efficiency.

Furthermore, despite challenges such as large-scale resource utilization [24], 5G is tending to be embedded in public infrastructures (e.g. medical services, gas stations) which mobilize emergency control resources for physical security support. These factors can be harnessed by policy-makers in order to preempt in emergencies.

C. Public infrastructural and geospatial indicators

Our third layer of the proposed architecture is focused upon the geographical dimension of the STSS, which will exert spatial-temporal impacts on overall security at a macro scale. It emphasizes the confluence of public infrastructures in facilitating transportation security and smart communication technologies [25], as what John Urry calls 'nexus systems' [26]. Public infrastructural designs based on communication technologies connect both transport entities and users to end services (e.g. 5G-enabled smart ambulances communicate in real time with traffic control systems under emergencies) [27]. Conversely, these public infrastructures, in which 5G is embedded, in return could generate geospatial data through mapping and coding, flowing back through 5G networks (2^{nd} layer) and right towards control rooms and standard organizations (1^{st} layer). Moreover, location design and master planning are vital and geographic dynamics would make difference either [28]. This would determine where the 5G-enabled sensor networks are deployed to what public infrastructures (considering the density and distribution).

This layer of the architecture also contains a set of geospatial factors that work synergistically with 5G-enabled infrastructures. Geographical information systems (GIS) tools are harnessed to identify geospatial indicators for multifaceted concerns of security management. The overall planning is thus dependent on spatial analysis of transportation resources which involves longitudinal and latitudinal coordinates and timely tracking of dynamic resource distribution [29]. Designing the STSS requires massive spatially referenced data generated by digital mapping (e.g. topographic wetness index, surface subsidence, wind shelter index) and non-spatial generated data (e.g. gas station distribution, medical services distribution). Whilst previous studies have placed significance on technology that impact upon the security of the STS, our study argue that the STS necessitates 5G-enabled infrastructures which are crucial to gather geospatial data. Quantifying and mapping those very aspects of geospatial influence would help urban transport managers make precautionary decisions for mobility efficacy and security control.

III. An experimental study: STSS in the city of Beijing

In this paper, we place our focus on the city of Beijing, China, to model and simulate our proposed architecture of STSS and give our suggestions for master planning. We firstly examined the national standard system (GB/T 33356-2016) applied to building smart city systems, and particularly, standardizing data created therein. Secondly, we collected seven types of geospatial data sets and carried out data modelling process to simulate and instantiate both the second and third layers of our proposed architecture, on the platform of ArcGIS (10.2). ArcGIS is a geographic information system (GIS) tool for geoscientific analyses, exploring the geographic information contained in vector (such as point, line and polygon) or raster (such as image) format. Undertaking the GIS modelling processes allows comprehensive analysis of urban transportation problems from various operational datasets, such as satellite remote sensing and ground based measurement, providing an optimized solution for the IoT enabled STSS in a state of art.

A. National standard systems for STSS

IoT contributes to ongoing data acquisition; the 5G-driven and IoT-enabled STS makes possible the big data analytics in real-time. However, although these technical instruments open up great opportunities, the accompanying privacy and security issues necessitate regulatory frameworks to normalize the implementation of the STS. Amongst many canonical smart city standards organizations (e.g. ISO, IEEE, IEC, ITU-T), China's National Standardization General Working Group on Smart City (SMCSTD) carried out 37 national standards for smart cities [30]. The national standard GB/T 33356-2016 "New Smart City Standards Index" was issued in 2016 and updated in 2018. This national standard index resonates with our proposed architecture of the STSS in a way of highlighting that the standard indicators for transportation services are focused on both the cyber-security and physical-level security.

The index of the cyber-physical level is used to assess the execution of security responsibility system in the process of implementation and management of the STS, enhance the overall coordination and top-level design of cyber-physical security control in smart cities, and fully construct and legalize the authorization system [31]. In the course of the operation of the proposed STSS, this standard index will strengthen the monitoring of information networks, alert notifications and information sharing, and fully enhance the cyber-security risk capacity and emergency response. This kind of stand index is usually applied to mobility services (e.g. car sharing platforms) and online transport transaction systems (e.g. train booking systems, automatic car park management systems).

The index of the geospatial security control refers to the definition and stipulation of requirements for data transmissions across public infrastructures and transport entities. This index is applied to evaluate the multi-dimensional decision-making system for traffic control and transportation resource distribution for the purpose of constructing public security surveillance systems. In Beijing, the large-scale deployment of IoT networks through which public infrastructures are coalesced further enhance the efficacy of traffic surveillance and detection systems, travel recommendation systems, and automated license plate readers, by the embedding of 5G-enabled sensor technologies.

In terms of data standards, GB/T 33356-2016 normalizes the coding structure of smart city data identifiers and clearly defines the rules of coding. This usually starts from data fusion practices. This allows Beijing's transportation departments to grant each data resource with a unique and non-changeable coding identifier for promoting the integration of data coming from different sites. This standard index is particularly crucial to the second-layer of the proposed architecture. This means that the coding process, identifiers and structure of data transmitting through 5G-enabled remote communication networks, ought to be legally standardized nationwide for universal access to data sources.

B. 5G-enabled base stations coverage and metro convenience index

The proposed 5G-enabled remote communication network of the STSS architecture is relied on the distribution of base stations that are supported by 5G communications and multi-antenna technologies. Figure 2 demonstrates an example of the coverage of the simulative 5G-enabled base stations within the scale of the sixth ring road in Beijing. This coverage is calculated by our GIS analysis on the basis of the DEM (Digital Elevation Model) – a 3D representation of a terrain's surface referenced by three-value coordinates (x, y and z) with the record of the elevation of every single pixel. The base station coverage is simulated by setting default parameters – the height of the base stations (default: 60m) and the distance of 5G signals (default: 1km). The white areas in the figure demonstrate geographic areas without 5G coverage. As the figure shows, the areas closer to the central Beijing are covered with more 5G signals. Modelling this coverage, on the one hand, will allow evaluation concerning how 5G would influence the commuting capacity of the traffic network, which further indicates the extent of security. On the other hand, it necessitates the analysis of sensor-enabled public infrastructures (e.g. medical services and gas stations) that transmit 5G signals between transport entities and themselves, which will be demonstrated in the next section. Our analytical process highlights that both the traffic network data for the former and the infrastructural data for the latter, are crucial to be integrated with the base station coverage in order to better identify security concerns.

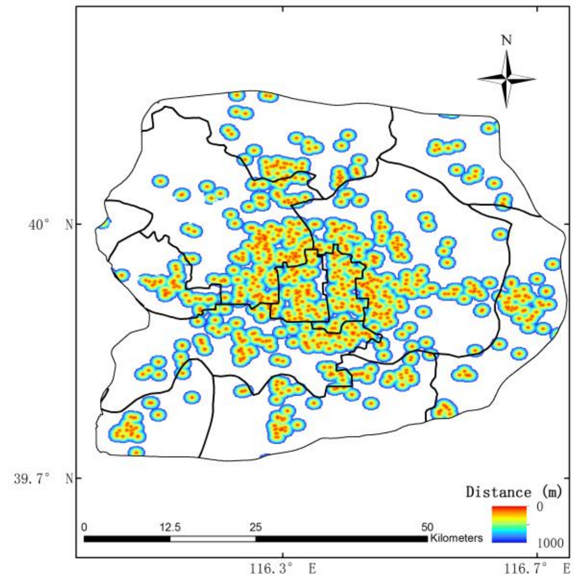

Fig. 2. Base station coverage within the sixth Ring of Beijing

Indeed, the analysis of the Beijing's base station coverage helps to evaluate the commuting capacity of traffic networks via D2D. For example, 5G data transmissions between traffic dashboards and traffic control rooms can provide users with just-in-time traffic information via smartphone apps or route guidance screens. Yet, it is also vital to timely indicate the size of everyday commuting across hundreds of public transport stations. This is especially useful to quickly respond to incidents occurring at various stations at the same time. Therefore, it is necessary to deploy 5G-enabled sensor networks to myriad public transports, with constantly generated signals being uploaded to the traffic control room. Amongst many types of public transports, we focus on metro stations, and claim that the extent to which metro station resources are arranged and distributed have an impact on the metro convenience index (Figure 3).

According to the figure, the higher the index is (approximating '1'), the more convenient the overall effect of commuting will be (approximating red areas). Apparently, the factors that determine the convenience index include the total transfer distance measured in time and the total times of line switching. And such factors further reflect the metro network structure and the location of the target point in the metro network. Metro stations located in the red areas require intensive deployment of 5G sensors and transponders in order to fulfill instant messaging via mobile devices and real-time interactions between mobile devices and metro infrastructures. Thus, given the security concern, convenience index suggests a reciprocal relationship between commuters and the metro system. High capacity of 5G communications will lead to high convenience index, thereby reducing the probability of unintended consequences regarding safety and security, and vice versa.

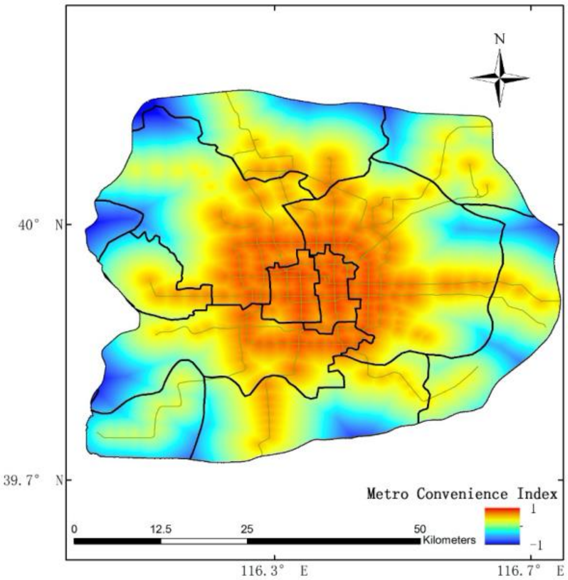

Fig. 3. Metro convenience index within the sixth Ring of Beijing

C. *Public infrastructural data and geospatial factors*

Our data modelling of the third layer of the proposed architecture is divided into two parts: public infrastructural data modelling and geospatial data modelling. Similar to calculating the base station coverage, the DEM analysis is used to model all data types involved in this layer. We argue that both public infrastructural and geospatial datasets are considered useful to precautionary decision-making so as to facilitate the security of the STS.

1) *Public infrastructural data modelling*

Public infrastructural data modelling suggests the relationship between the IoT network and public infrastructures that support just-in-time communications via 5G. This also indicates the extent of geospatial security in the physical term. Here, we focus on medical services (e.g. hospitals, clinics, pharmacies) and gas stations as essential public infrastructures that help to remedy security concerns. Medical services play an important role in medical treatments in emergency, e.g. traffic accidences, whilst gas stations are critical in supporting smooth commuting. Similar to the base station coverage, the DEM analysis set certain threshold value (e.g. within 3km) to analyze the geographic scope of these two services.

Moreover, these general infrastructures embedded with the IoT network will enable real-time information sharing with transport agents. Realistically, it is unlikely to have 5G in every single medical service and gas station. Take medical services for example, 5G technology has gained traction amongst healthcare practitioners to facilitate diagnosis. But it is necessary more to those with high quality services and making use of large-scale mobile health systems and health monitoring systems, such as wearable devices, smart ambulances, and so on, in order for seamless connection between patients and medical service crew [32][33]. This means that those services in high demand for 5G would, on the one hand, need to be entitled with standard and authoritarian service capabilities. Those less qualified, on the one hand, need to overhaul the telecommunication system in order to realize data sharing across the entire urban healthcare system, and taking a further step, data integration.

We use vector point data to model the distribution of both medical services and gas stations, as shown in Figure 4 and 5. The figures show that there are 8239 points of medical services and 592 gas stations within the area of the sixth ring road of Beijing. When building the 5G network, it is necessary for decision-makers and practitioners to not only pay attention to the density of service points (the figures as reference), but also to examine the qualification of 5G arrangements for each service point. For those located between the Fourth and Sixth Ring would need to ensure seamless communications with those inside of the Fourth Ring (closer to the central Beijing). Critical precautionary decisions need to be made in due course.

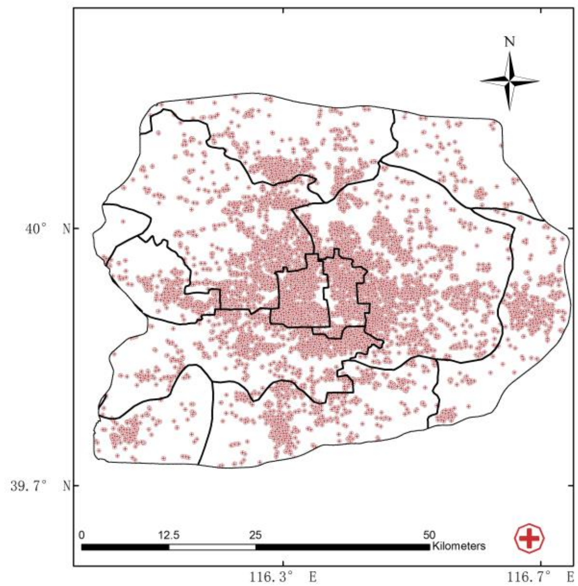

Fig. 4. Medical services distribution within the sixth Ring of Beijing

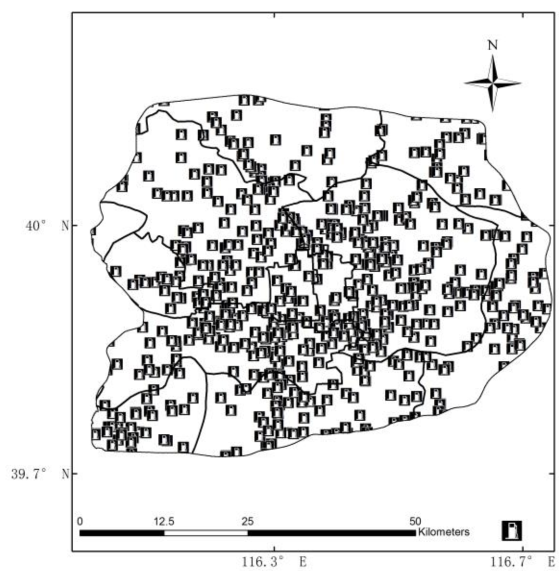

Fig. 5. Gas station distribution within the sixth Ring of Beijing

2) *Geospatial data modelling*

Geospatial data reflect how different types of geospatial factors impose external and indirect influence on the STSS from the geospatial point of view, including wind shelter index, topographic wetness index and surface subsidence, which are modelled through DEM. All of these types of data are considered as frames of reference for practitioners to make precautionary decisions for smart transportation security.

Topographic wetness index. Our DEM data sets derive the second order parameters of slope, aspect and general curvature, and the computation of these parameters alongside precipitation data further derive topographic wetness index (TWI). The precipitation data indicate predicted volume of rainfall over a certain timespan in a particular locale. This data set is gathered from ERA-interim [34]. TWI is a measurable indicator that is used to estimate the extent to which unconsolidated, permeable materials above impermeable bedrocks, are saturated. It is impacted by the precipitation dynamics and it considers hydraulic conductivity to be constant in a soil mantle overlying relatively impermeable bedrock, such as urban highways [35].

Figure 6 presents an example of the spatial-temporal variance of precipitation in Beijing around July 21, 2012 (from July 16 to July 26), during which period a destructive rainstorm occurred. An animated GIF image corresponding to Figure 6 is provided in the supplementary file. This figure indicates that the water precipitation (whether in liquid or solid phase) is usually a short-term phenomenon. However when it happens, the magnitude could be remarkable, causing waterlogging in bottomland and threatening the transportation security. IoT networks in which sensors are installed to detect rainfalls and runoff changes, are used to indicate overall TWI parameters. This indication of dynamic TWI can be used to deploy the urban drainage systems alike which make direct influence upon road capacities under the waterlogging circumstances.

Wind shelter index. The three second order parameters of DEM data are also used to parameterize the effects of the wind shelter index (WSI) of Beijing's terrain through terrain analysis. This indicates the impact of wind in the transportation system. The areas with high value of WSI are exposed to wind, whilst those with low value are wind-shadowed. This means that the areas with low WSI value may lead to subsequent issues with low visibility, especially under snowy weather conditions. This can further impact urban mobility, resulting in traffic congestions or even accidents.

Figure 7 shows the dynamic schema of 10-meter meridional wind and 10-meter zonal wind in Beijing around July 21, 2012 (from July 16 to July 26), during which period a destructive rainstorm occurred. An animated GIF image corresponding to Figure 7 is provided in the supplementary file. This figure indicates that the wind speed and direction frequently changed over time. High speed wind in a specific direction may have notable influence on safety when people drive on the road, especially on highways. In Beijing, many roads are equipped with magnetometer sensors and ultrasonic sensors which are used to detect road capacity and environmental conditions. Alongside the use of remote sensing [36], data gathered from various sites through IoT networks that indicate WSI are fed back to the control center for traffic control decision-making. WSI, thus, can be used to analyze the potential of wind in influencing the transportation security at specific localities.

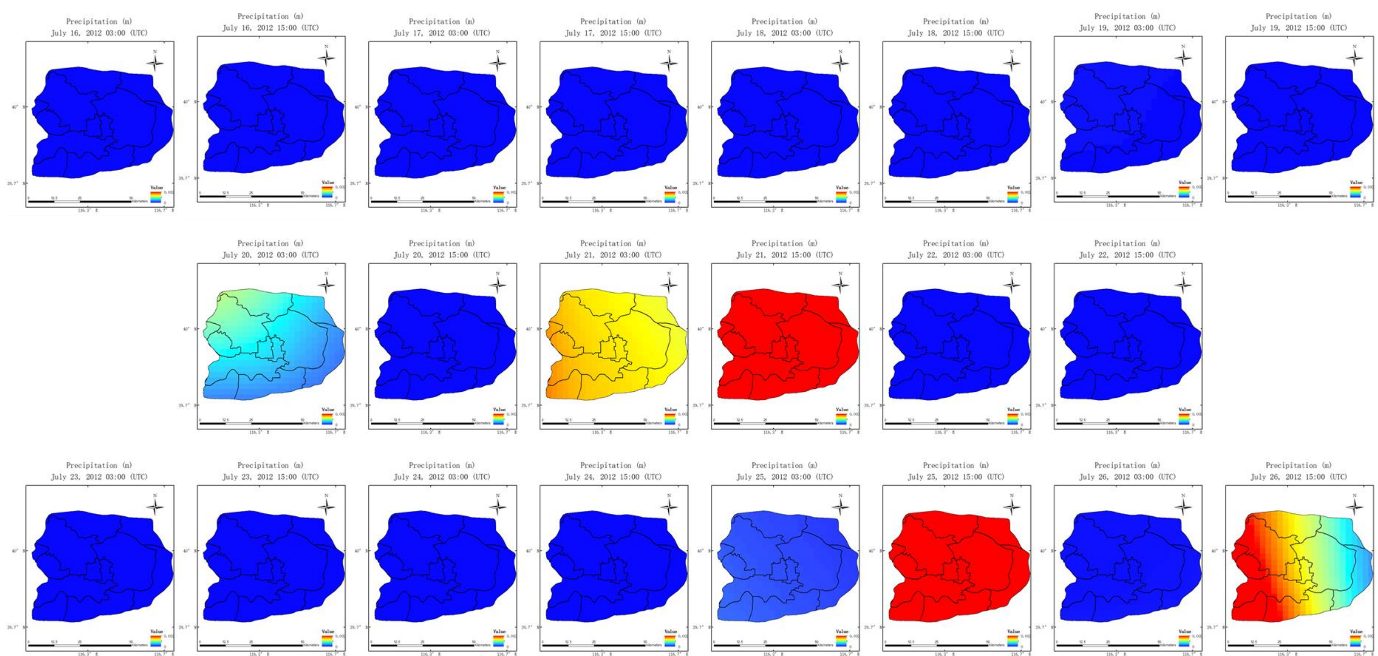

Fig. 6. Dynamic schema of precipitation in Beijing from July 16, 2012 to July 26, 2012 (two images per day at 3:00 and 15:00 UTC)

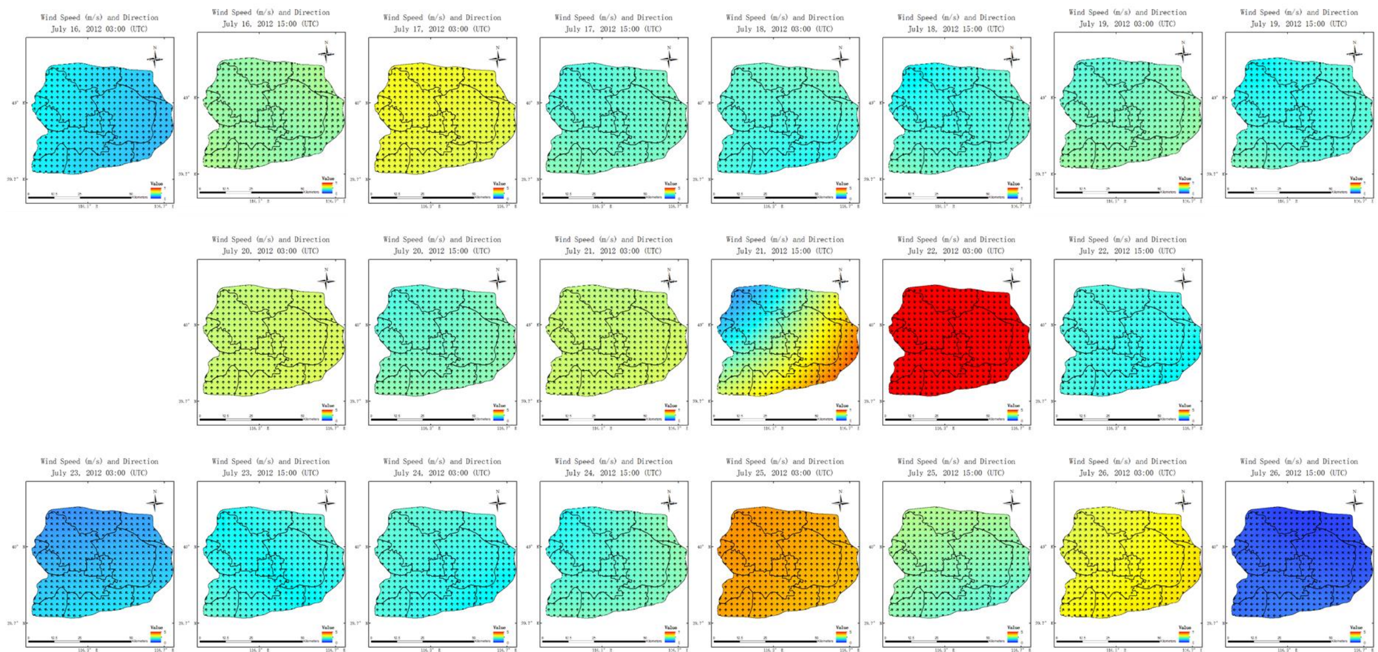

Fig. 7. Dynamic schema of 10-meter meridional wind and 10-meter zonal wind in Beijing from July 16, 2012 to July 26, 2012 (two images per day at 3:00 and 15:00 UTC)

Surface subsidence. Surface subsidence is another type of indicator that makes indirect influence at the geospatial level of the STSS. It refers to a phenomenon that the elevation of the earth's surface at a particular location decreases continually in a certain period of time, which takes place in all over the world, including Beijing [37]. This indicator is calculated by subtracting DEM data in one timespan to that in another. Surface subsidence data are crucial for transportation facilities with high geospatial requirements, such as metro lines. For example, if the surface subsidence speed is fast in the area where metros pass through, the track lines will be deformed after a while, which may lead to tunnel wall rupture and train derailment. The cause of this is multi-fold, but taking Beijing as an example, this is resulted by long-term over-exploitation of groundwater resources [38]. Our GIS analysis shows that the subsidence rate in the east and north of Beijing is substantially higher than that in other areas; the groundwater in these areas is overexploited. More specifically, Figure 8 shows the surface subsidence map of the region within the sixth Ring. It clearly demonstrates that point B is of the highest value of subsidence (-155.86 mm/year) in comparison with the point A and B, with value of 1.94 mm/year and -44.52 mm/year respectively. When it comes to IoT, surface subsidence exerts impact on underground transport systems more than other types as IoT networks are usually deployed underneath the surface; it is therefore impacted by surface subsidence. We suggest urban planning officials to pay more attention to the areas like B when IoT networks are deployed to the underground transport systems located in these areas.

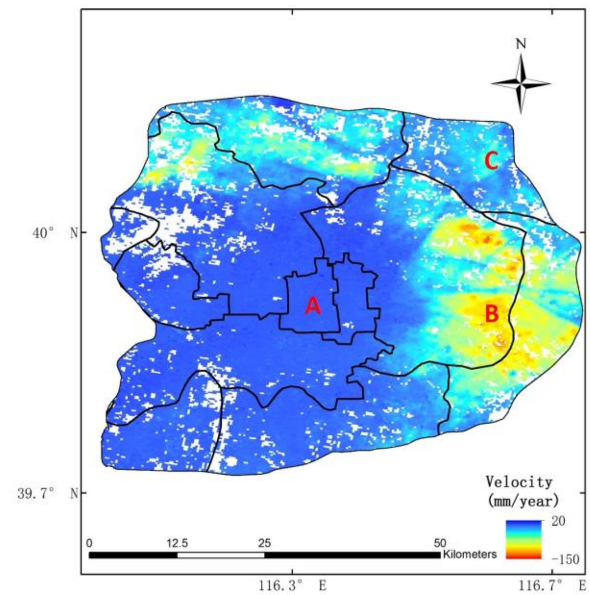

Fig. 8. Surface subsidence within the sixth Ring of Beijing

IV. Discussion of the Heterogenous Security System

Despite the fact that IoT is ultraefficient, the contemporary smart city is meanwhile confronting wicked issues of unstable and insecure data transmissions and vulnerability of overall transport systems. One of the causes of these issues is that data from different sites are not unified and standardized in terms of data format, structure, and attributes [39]. Government officials would need to embrace the top-level design vison to carefully mobilize urban transport resources in order to shape a more secure control environment, specifying the standard system and strategic management and control of unintended consequences of standardization.

Citizens qua users interact with STS service through mobile devices and various means of transport. Therefore, a standardized IoT network with 5G coverage is of upmost importance to industrial players who actually design and implement sensors, transponders, smart cards, and so on. The modelled 5G base station coverage and metro convenience index are useful indicators to make critical decisions of the extent to which a particular type of transport at a particular locale is equipped with IoT networks. For example, 5G facilities should be embedded more into public transports with high population density. Rather than taking post-event measures, practitioners should pre-empt to give priority to these places with respect to resource allocation for emergency response if incidents happen.

On a more macro level, public infrastructural designs and geospatial impacts impose indirect influence on security management. Instead of considering public services as separate to transportation, it is crucial to leverage 5G networks to connect them together for the purpose of instantaneous and simultaneous problem-solving for emergencies under various circumstances, such as medical services for road collisions and injuries, gas station services for vehicles with problems on the road. Furthermore, the study makes special contribution to IoT-enabled STSS by simulating a set of geospatial indicators which, from different spatial-temporal dimensions, support master planning of IoT networks in facilitating the running of STSS.

V. Conclusion

The proposed STSS architecture is supposed to address security concerns that many smart transportation innovations are currently facing. It is advantageous in combining the cyber-physical system deployed in overall IoT network and a set of geospatial impacts, rather than simply overstating the speed and volume of big data transmissions across IoT networks [40][41]. It is identified as a heterogenous system that provides a guide for smart transportation practitioners to consider strategic management of security and implementation of IoT-enabled STS. However, the proposed architecture on its own also has limitations. IoT networks in cities are not simply seen as technical systems that rely on computation, algorithms and simulation, but instead are socio-technical assemblages that require legitimate and social interventions for the purpose of examining its feasibility and applicability in different urban contexts.

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