SMART ARCHAEOLOGICAL TOURISM: CONTENTION, CONVENIENCE AND ACCESSIBILITY IN THE CONTEXT OF CLOUD-CENTRIC IoT

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ABSTRACT

The spread of digital technologies offers a great potential for the creativity and innovation in all aspects of tourism industry. The integration between advanced technologies of ICT and tourism industry plays vital role in enhancing the tourism services and experiences, particularly, in the context of archaeological tourism. Following this, this study proposes a protocol that offers tourists site/destination and experiences according to their preferences. More specifically, tourists can express various preferences regarding the type of tourism site, their contention level in order to avoid crowded ones, the accessibility and convenience of different sections of a site, and the distance and congestion of the paths lead to such site …etc. Our Contention, Convenience and Accessibility based Smart Tourism-destination Approach (CASTA) is presented in this paper to offer online services for tourists assuming that they are always connected and they do not have advanced IT skills. A tourist has only to send a preference message that specifies all the personal constraints via a smart hand held device. A control unit that resides on the cloud analyzes the message and suggests a tour to certain sites and their sections based on the tourist preferences. Information about tourism sites and their sections, in terms of contention, convenience, and accessibility, is collected by wireless sensor networks and sent to the control unit via a gateway node. Results of simulated experiments of CASTA have shown that it outperforms the shortest path approach which suggests a tour based solely on the distance toward those tourism destinations. Moreover CASTA outperformance shortest path approach that takes the quality of network connections available over the selected paths.

1. INTRODUCTION

It is apparent that the development of information and communication technologies (ICTs) has transformed the tourism industry from the point of views of both the industry structure and business strategies, and practices (Buhalis & Law, 2008). Fowling this, it is acknowledged that the considerable development of information technology, particularly, the applications of the internet has radically changed the tourism industry (Ho & Lee, 2007).

Smart tourism can be defined as integration between ICT and urban tourism platform in order to offer services and related information to tourists pre and during their travels. Such integration is based on recent development in mobile computing and advanced technologies such as cloud computing, artificial intelligence, and Internet of things (Wang, Li, & Li, 2013; Zhang, Li, & Liu, 2012). Whereas, Batty, Fosca, Bazzani, & Ouzounis (2012, p. 481) indicate that a smart city can be determined as "a city in which ICT is merged with traditional infrastructures, coordinated and integrated using new digital technologies".

Internet of Things (IoT) interconnects things that can be found around us in our current and future daily life. While having certain level of intelligence, sensing capable things can be connected to the future internet so they are able to communicate, coordinate, compute, activate actions, and can be remotely controlled (Atzori et al. 2010).

IoT as a concept was firstly mentioned by Kevin Ashton (MIT) in 1999. He defined IoT as a network that connects anything in anytime and anyplace in order to identify, locate, manage and monitor smart objects (Mingjun et al. 2012). IoT generates automatic real-time interactions among real world object using advanced technologies such as Near Field Communication (NFC), Radio-Frequency Identification (RFID), Sensors, and mobile phone devices, etc. Mobile computing emergency has supported a superfluity of applications that have contributed to the development of the IoT (Borrego-Jaraba et al. 2011).

Relying on cloud computing and the internet of things (IOT), smart tourism seeks to employ intelligence perception of all types of tourism information to get the acquisition and the adjustment of real-time tourism information through mobile internet or internet terminal equipment (Mackay & Vogt, 2012).

Recently, considerable literature interest has grown up around the theme of ICTs applications in different contexts of life. Despite the breadth of such studies, little attention has been paid to smart cities and its tools in the context of IoT and smart tourism. Thus, the main purpose of this study is to propose a protocol that fits in these complementary contexts in order to serve e-Tourism in general and archaeological tourism in particular.

The most noticeable contributions that have been made in this paper could be summarized as follows:

1- A general architecture for smart tourism has been proposed with the role of its various components described. As a cloud-centric IoT based, this architecture assumes the existence of sensors in tourism sites sections and road segments, the availability of cellular or WiFi wireless connection for an always connected tourist, and smart phone or other hand held device is available for each tourist.

2- The details of a Control Unit (CU) that exists on the Cloud and that receives, analyzes, and generates the required information for a tourist has been presented and explained.

3- An analytical description of a model that cloud be used to differentiate and compare between various tourism sits, their constituting sections, and the paths that lead to these sites has been illustrated and used in the program that simulates the proposed environment.

4- The concept of Smart Tourism Site Convenience (STSC) has been introduced and evaluated for the first time in the context of IoT. We define STSC as the assurance for a tourist of the environmental and health suitability of the tourism site done through the collection of relevant information via sensor devices accessible through IoT.

5- Accessibility, convenience, and contention of tourism sties' sections, in addition to road paths congestion, and distance have been combined and used for the first time, up to our knowledge, in an evaluation and differentiation between various tourism attractions according to a tourist preferences.

The rest of this paper is as follows. Section 2 presents a literature review of background and related works that are of important interest relative to the work done in this paper. In section 3, the assumed network model, CASTA general architecture, CASTA protocol phases and analytical model, and the simulation environment have been illustrated in details. The results of several simulated experiments are discussed in section 4. Finally, we conclude with section 5.

2. LITERATURE REVIEW

In recent years, the scientific debate on smart cities and smart tourism destinations has been growing rapidly (Del Chiappa & Baggio, 2015). Komninos, Pallot, and Schaffers (2013) postulate that the essential elements of smartness for any targeted city are

human capital, infrastructure, and information. Xiang, Gretzel and Fesenmaier (2009) argue that tourism informatization and intellectualization would represent the future tendency of the integration of the internet of things (IoT) technology into the tourism industrial upgrading. Accordingly, Nam and Pardo (2011) explain that the major priorities for any smart tourism destinations can be depicted by undertaking a demand-side or a supply-side perspective. Consequently, enhancing different tourist experience and offering intelligent platforms to collect and distribute information within local Stakeholders.

Elsewhere, Guo, Liu, and Chai (2014) propose the embedding convergence of smart cities and tourism IOT in China. They further indicate that the emerging smart tourism matches China economic growth and industrial transformation. Poslad, et al. (2015) indicates that the development of the Tripzoom system has been introduced. This mobile sensor-based system aims to achieve sustainability goals by promoting mobility shifts. This is done by observation of common multiple urban transportation means, and the generation of individual and group mobility profiles that is coupled with the use of a targeted incentivized marketplace. After testing the system in three European country cities for six months the main findings were that the system has achieved a level of behavioural shifts in travelling manner.

Cultural Heritage Areas together Context-Aware Systems present a great opportunity where the Ambient Intelligence (AmI) paradigm can be successfully applied. However, the need to design web applications by considering rich internet interfaces requires often a careful study before to include sensor data from the ambient context (e.g. coordinate for position or environmental data). Whereas, Angelaccio et al. (2014) propose a tool which is MVC-based JavaScript and dynamically connected with sensor data has been proposed to service a cultural site be developing a map area using image gallery. To test this smart image gallery system, called SMART VILLA, an ancient Renaissance Villa, called Villa Mondragone, has been selected as a context of mobile and safe cultural access. NFC proximity smart devices were used to locate each point of interest inside ancient rooms.

Similarly, Palumbo (2015) has suggested the Smart Tourist App (STAPP) which assists mobile tourists via the integration between traditional city card and the mobile devices specifications. This integration is based on qualitative data collected through questionnaires conducted to a panel of Italian tourists visiting Palermo and Rome over a three months period of time. An evaluation of the impact of mobile technology in augmenting and streamlining the tourist experience represented, via STAPP, has been conducted. STAPP integrates Kano Model (KM) and the Analytic Hierarchy Process (AHP) methodologies. These methodologies allow categorization and ordering of service attributes based on how they are perceived by traveler tourists.

Almobaideen et al. (2015) has proposed a new approach using combined criteria to provide a service that suggests geographical routes based on user preferences in terms of public transportation and service. Public transport mean preferences could include bus, train, metro, and walking … etc. Service related preferences include the best wireless network connection such as GPRS, 3G, and 4G … etc, along the available paths. The combination of these two preferences is highly desirable since a continuous and good internet connection is crucial while tourists moving to sites. This approach has been modeled and simulated via C++ program and then compared with other approaches, one of them is the shortest route selection approach. Results have shown that the combined criteria outperform others in selecting geographical routes while considering the preferred public transport means as well as staying connected with higher quality network connections.

3. THE PROPOSED IDEA (CASTA)

The network model, general architecture, the main phases of the proposed protocol, and the simulation environment are discussed in sections 3.1, 3.2, 3.3, and 3.4 respectively.

3.1 Network Model

The proposed protocol assumes the following transportation network model:

1. The transportation network is represented as a graph G with set of nodes N, edges E and weight W.
2. Each $n \in N$ is a transportation station. Some stations are terminal for particular transportation lines.
3. Each $e \in E$ is an undirected edge represents a road segment that connects two transportation means.
4. Each road segment represents a transport line, for example Bus line 3, and has its own characteristics such as network coverage, duration time, and its departure and terminal stations.
5. Each $w \in W$ represents a road segment weight that is calculated based on the user preferences.
6. Each tourism site has a station close to it.

3.2 General Architecture of CASTA

The architecture of the proposed protocol is illustrated in Fig. 1. As the figure shows, the most im-

portant and main components in the architecture are as follows: The tourist hand-held device which is assumed to be GPS enabled and allows the tourist to send a preferences message and get back the required feedback.

Each tourism site is assumed to be equipped with small wireless sensors that should be placed in various sections, rooms, squares …etc of that site (Al-Hasan et al. 2011) (Jassim and Almobaideen, 2013). These sensors collect various information that could be of interest to tourists such as the temperature, humidity, air quality, and visitors' number. These information is sent to the GateWay (GW) node which is a more computation and communication capable device connected to a permanent power source. The GW collects and possibly aggregates this information and sends it to the CU to be placed in the Tourism locations DB.

The control Unit (CU) is a major component which resides on the cloud and performs necessary computation based on information that exists in various databases. A detailed description of the CU and the components it contains and interacts with is shown in Fig. 2.
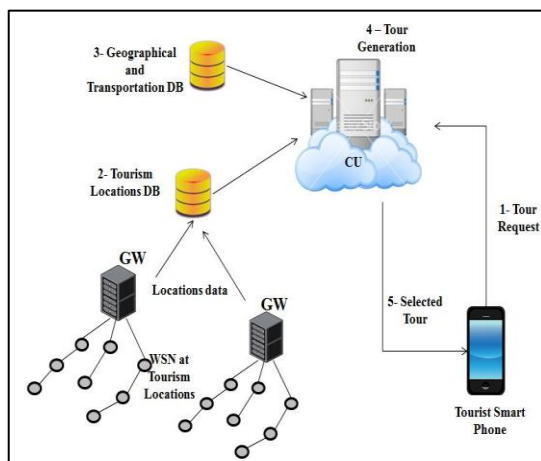

Figure 1. General architecture of CASTA

The Following details are the description of the components presented in Fig. 2.
- *Preferences Message:* Sent from the user smartphone to the control unit and it contains the following fields:
  1 *Time:* The time when the message is created.
  2 *Location:* The user location when the message is created or read by the GPS device.
  3 *Destination:* The user intended destination.
  4 *Type of the tourism sites:* A tourist specifies the type of the tourism sites that he would like to visit such as archaeological, historical, natural and other types of tourism sites.
- *Control Unit (CU):* A cloud-centric IoT controller where user data are processed and analyzed. It

is connected to the geographical maps and transportation DB, network coverage DB, and tourism locations DB. The CU consists of the following modules:
1 *Reception:* This Module receives the user preferences message and inspects its fields.
2 *Analysis:* This module analyzes the information retrieved from the message and requests transportation information that is available between a tourist current location and the suggested tourism destination sites which can be found in the tourism locations database. Among the paths that have been found to lead toward a destination, the analysis module selects the best one after consulting the network coverage database for the corresponding network connection quality available over these different paths.
3 *Route generation:* This module generates the best path based on the analyzed information and using Dijkstra's routing algorithm.
4 *Route visualization:* This module sends the information back to the user and displays it on the user Smartphone.
- *Databases:* They are connected to the CU. There are three database types:
1 *The geographical and transportation database:* Contains all roads maps and transportation records including the provided services available on the transportation means such as Wi-Fi on board.
2 *The network coverage database:* Contains information about all geographical areas with its corresponding quality of cellular network coverage.
3 *The tourism location database:* Stores information of the location of different attractions, their classification, and current level on contention in each site …etc.
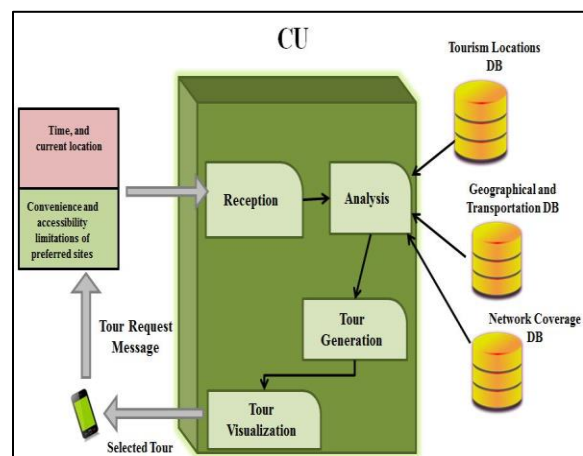

Figure 2. Details of the CU components

3.3 CASTA phases and analytical description

The proposed protocol consists of three phases; preferences message transformation, user preferences analysis, and geographical path selection based on the analyzed preferences.

In the first phase, user preferences are transmitted in a preferences message from user smartphone to the control unit. The preferences message includes the user location, the desired type of tourism sites, whether there is an accessibility limitation or not, and time limitations to visit a tourism site, if any. This message can be transmitted over Wi-Fi or cellular networks.

During the second phase, the control unit retrieves the field of the preferences message using the reception module. Then, it analyzes the data which were retrieved using the analysis module. The second phase consists of the following steps:

1   The reception module retrieves the user preferences from the message and based on the preferred type of attraction sites it searches the tourism location database for a suggested set of sites to be visited. The distance to those sites is also taken into account according to equation (1).

$$W.Site_i = \alpha \times Cont.Site_i + (1 - \alpha)Dist.Site_i \dots (1)$$

Where α is a weight factor which could be used to give more importance to a certain term in Equation (1) over the other. In the experiments presented and discussed in section 4, we have set α to 0.7 so that the contention level of a site (Cont.Site$_i$) participates more, in the whole weight calculation (W.Site$_i$) of a site (i), than the distance to that site (Dist.Site$_i$).

2   Each one of the suggested sites could contain multiple sections. Some of these sections could not be accessible by a tourist with special needs. Should the preference message indicate that the tourist has accessibility constraints, then CASTA excludes those inaccessible sites from the list of suggested sites. For each of the rest of sites, and after consulting the tourism locations DB, CASTA calculates a weight that differentiates between various sections of that site as in equation (2).

$$W.Sec_{i,k} = \beta \times Cont.Sec_{i,k} + \mu \times Dist.Sec_{i,k} + \theta \times Conv.Sec_{i,k} \dots (2)$$

Where $W.Sec_{i,k}$ is the calculated weight of section (k) at site (i) which depends on three factors weighted by three parameters β, μ, and Ø, that all sum to one, i.e. β+μ+ θ=1 . The first factor is the level of contention at section ($Cont.Sec_{i,k}$). The second factor is the distance towards that section ($Dist.Sec_{i,k}$). While the third and last one is the level of convenience a tourists is expected at that section ($Conv.Sec_{i,k}$). The values 0.4, 0.2., and 0.4 have been used to conduct the experiments shown in section 4 for the three mentioned weighting parameters above respectively.

3   The next step is to find paths towards the suggested sites that satisfy two characteristics; namely less congested and better coverage by wireless network connections. Wireless network could be a cellular network or a WiFi hotspot, available nearby or over the bus. The analysis module retrieves all road segments information from the transportation DB and the network coverage DB in order to calculate the weight for each road segment using equation (3) which illustrates the way of giving weight to each road segment from which different paths constitute.

$$W.Seg_s = \delta \times NC.Seg_s + (1 - \delta) \times Cong.Seg_s \dots (3)$$

Where $W.Seg_s$ is the weight assigned to a road segment (s), that is based on the quality of network connection covering road segment ($NC.Seg_s$), and the current level of congestion experienced on that road segment ($Cong.Seg_s$). δ is a weight factor that is used to specify the importance of each term in calculating the final value of a segment weight. We have set δ to 0.3 in the experiments presented in section 4.

In the third phase, the route generation module in the CU uses the information from the analysis module (each road segment and its corresponding weight) to compute and select best geographical routes toward the destination using Dijkstra algorithm (Cormen et al. 2001). This set of possible best paths are then sent back to be displayed on smart phone of the mobile user by the route visualization module. The displayed information on user smart phone should contain a route map, the transportation information, and a time schedule to be followed during the trip.

3.4 CASTA simulation environment

The proposed protocol has been simulated based on the adaptation of the simulator that has been introduced in (Almobaideen et al. 2015). This simulator is a C++ program that has been adapted for the purpose of this study through three steps. In the first step, the transportation network topology, described in subsection 3.2, is constructed as a set of road segments each one connects two transportation stations by the specified transportation means. Each road segment has its own characteristics such asthe network coverage, duration time, and its departure and terminal stations. Tourism sites are then randomly distributed over the specified geographical area covered by the transportation network.

During the second step, another part of the program has been implemented to simulate the architecture described in subsection 3.2. This part of the simulator has then been used to simulate a tourist preference message that is received, analyzed, and based on which the required calculations of the sites, sections, and paths weights are performed as described in subsection 3.3. The third and final step applies Dijkstra algorithm to find the path with the optimal weights toward the suggested tourism sites (Cormen et al. 2001).

4. RESULTS AND DISCUSSION

In this section we present the results of evaluating CASTA approach against shortest path and another approach which prefers path with better network connections as well as being shortest ones (Almobaideen et al. 2015). We refer to the later approach as shortest-with-NC in the figures show in this section. In the next four figures a tourist moves between six different locations in an order that starts with the first and ends with the sixth. We assume that the tourist wants to visit just six different locations or sites, out of twelve available locations. The selection of these six locations out of the whole available is based on either the shortest distance between these locations, as done by the shortest path approach, or based on combined criteria that take roads congestion, intra-site contention level and convenience, and the quality of the network connections available through the paths towards those destinations, as is the case with CASTA. Shortest-with-NC takes the quality of the network connection to the selection criteria of the shortest path approach. Results shown in these figures represent an average of ten different random scenarios that have been conducted for all approaches.

In Figure 3 the contention level perceived by a tourist who visits six different locations or sites is shown. One can notice that CASTA achieves far less contention level compared to the shortest path approach, which is better than shortest-with-NC, and for all the visited sites. This is because CASTA selects the least six crowded sites to be visited in the tourist's tour since it takes the contention level, in each site, into consideration as one of the metrics of the selection criteria and gives a weigh that equals to 0.7 in contrast to 0.3 that is given to the distance. On the other hand, the shortest path approach relays only on the distance between difference locations to choose six locations out of all available ones. It is important to mention here that CASTA noticeably outperform shortest path approach for the very first locations since it has more options to choose compared to the case for later locations. Shortest-with-NC gives 0.7 weight to the quality of the network coverage and

0.3 to the distance. This apparently results in the selection of very busy sites that are fare beyond the contention results by the shortest path approach.
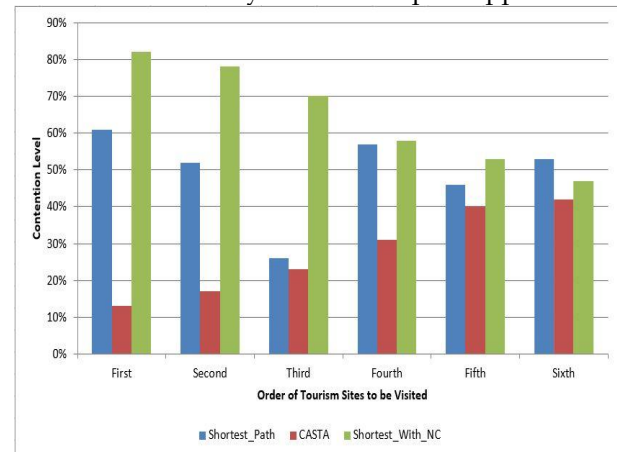

Figure 3. Locations contention Vs. order of locations to be visited

In *Figure 4*Fig. 4 the distance between a tourist current location or site and the next site of a total of six is shown as the tourist is moving around. One can notice that CASTA selects paths with higher distance compared to the shortest path approach and for all sites visited. The fact that shortest path approach concentrate solely on selecting paths with least distance allows it to move a tourist along the shortest paths available. In contrast, CASTA selects the lesssix crowded, less congested, and better wireless network served sites to be visited in the tourist's tour. Shortest-with-NC approach is able to stand in a middle situation regarding this metric. This is because it concentrates on both the distance and the quality of the network connection over the available paths. This multi-dimensional selection criteria of CASTA results in a penalty of going along longer paths, which not necessarily results in longer trip time due to the factor of congestion along these paths as could been seen in Fig. 5.
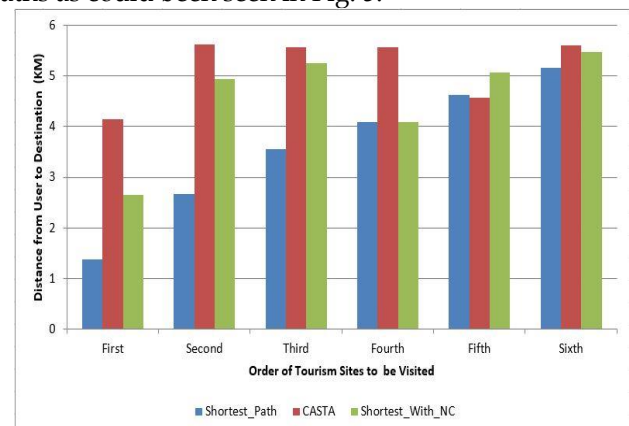

Figure 4. Distances from user to destination VS. order of locations to be visited

The level of congestion over the selected paths between tour sites as a tourist moves from the first site to the sixth is shown in Figure 5. Except for moving from the fourth to the fifth sites, CASTA is able to route the tourist through paths that are less congested or almost as congested as the paths chosen by the shortest path approach. CASTA is also better than shortest-with-NC except for moving from the second to the third sites. CASTA would have been able to select even lesser congested paths, but it did not because it also searches for paths with better network connections towards the less crowded, i.e. have less level of contention. Guiding a tourist long less congested paths by CASTA could compensate for those paths being longer than those results from using the shortest path or shortest-with-NC approaches.
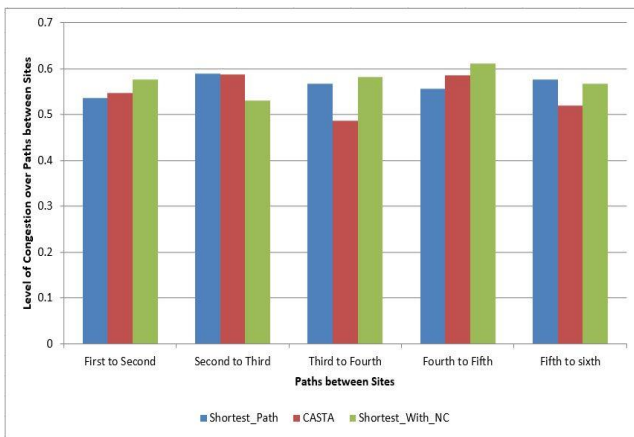

Figure 5. Level of congestion over the path between sites

*Figure 6*Fig. 6 shows the quality of wireless network connections over the selected paths between sites. Three out of the five paths have better quality of wireless network connection selected by CASTA. The selection criteria give a smaller weight to the quality of network connection that equals to 0.3 compared to the weight assigned to the level of congestion as 0.7. This results in modest superiority of CASTA over the shortest path approach regarding this metric. In contrast, and since shortest-with-NC takes into consideration the quality of network connection, CASTA could not be better than shortest-with-NC but over two paths out of five.
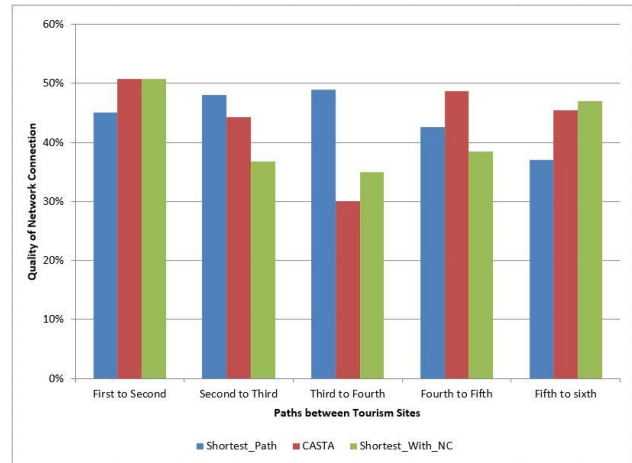

Figure 6. Network connection quality over the path between Locations/Sites

The next four figures represent results of evaluating CASTA approach in selecting a certain sections inside a tourism site according to contention, distance, and convenience factors. To combine these factors inside a single selection criterion they have been given weights that equals to 0.4, 0.2, and 0.4 respectively.

Fig. 7 presents the level of contention in different sections in a particular site that contains thirty sections. The sections are placed on the x axis is a relative one and should be looked at according to best order suggested by each of the two approaches. The order suggested by CASTA represents the best order that has less contention, less distance, and more convenience. Compared with CASTA, the shortest path approach chooses the order of those sections to be visited based only on distance which results in visiting varying contention level sections. For example moving to the first section suggested by shortest path results in visiting a section with 70% contention level, while moving to the first location suggested by CASTA, which could be different than that suggested by shortest path, results in visiting a less than 10% contention level section. Notice that the last five sections are not accessible and so they were not considered by CASTA and their contention level information has not been measured. Shortest-with-NC gives the same performance as the shortest path approach since the network connection quality inside a site is assumed to be the same for all sections and this applies for Fig. 8 and Fig. 9 as well.
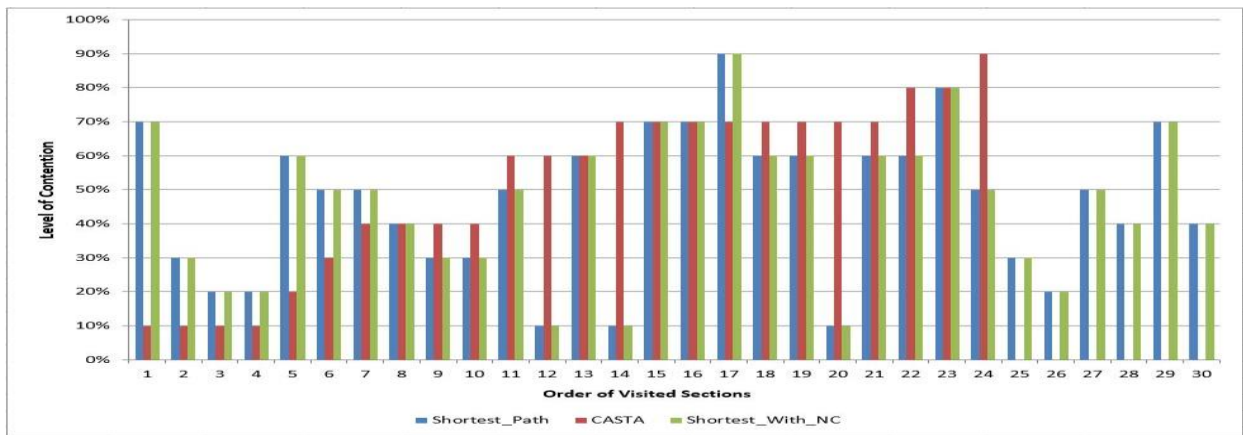
Figure 7. Level of contention in different sections Vs. order of sections to be visited in a particular site

*Figure 8*Fig. 8 illustrates the distance between sections in the same site as that shown in Fig. 7. The sections are placed on the x axis according to the same order as in Fig. 7. Shortest path approach is able to order the sections in an ascending order re-

garding the distance between these sections, while CASTA produces an order that varies considerably in terms of sites inter distance. CASTA is still able to exclude those inaccessible sites.
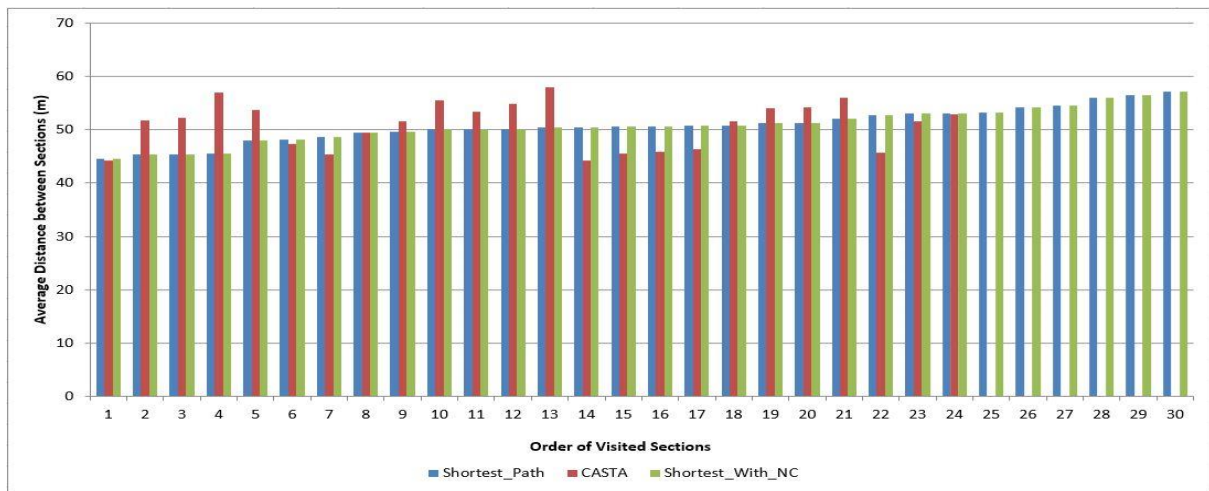

Figure 8. Average distance between sections Vs. order of sections to be visited in a particular location
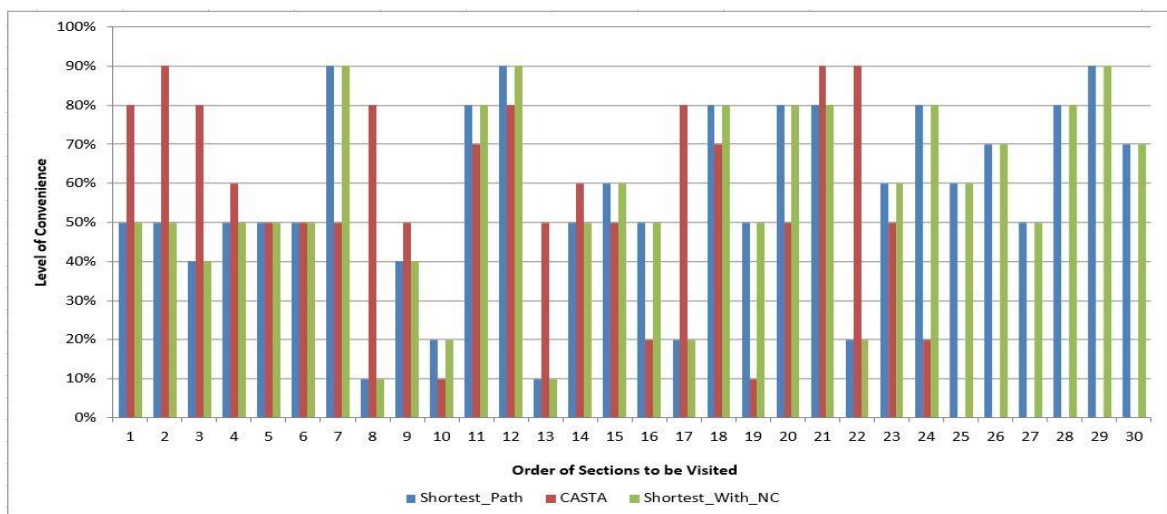

Figure 9. Level of convenience V.s. order of sections to be visited.

*Figure 9*Fig. 9 presents the level of convenience in different sections in a particular site that contains thirty sections. These sections are placed on the x axis according to the same order as in Fig. 7. The last five sections are not accessible and so they were not considered by CASTA and their convenience level information has not been measured.

The ordering of section in this experiment provides more convenient section in the beginning of the list than in its rear. CASTA does not provide sharp results as it does in regard to the contention experiments as shown in Figure 7. This is because we have assumed a scenario where the convenience level$Conv.Sec_{i,k}$, see equation (2), of most of the sections is low to test the behaviour of CASTA in such constrained cases. We can notice that the performance of CASTA is still acceptable in that it leads a tourist to noticeably convenient sections at the start of the suggested list relative to other sections suggested later on.

*Figure 10*Fog. 10 shows the results of the average number of sections to be visited in each site of a six different and randomly generated sites. CASTA is able to limit the number of resultant sections to those accessible which are less than the whole number of available sections. Shortest path and shortest-with-NC approaches on the other hand suggest all the available sections since they do not take the accessibility factor into account.
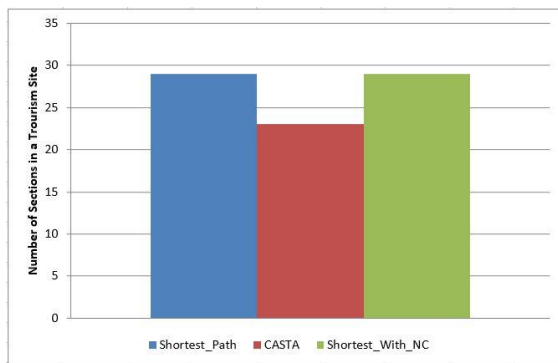

Figure 10. Average number of sections to be visited in all Sites

A tourist cloud, due to time limitation, wish to visit some of the sections that exit in a certain site. In this case, the ordering of these sections according to distance only could be misleading as shown in Figure 11. This figure shows the time needed to visit ten sections out of thirty sections in a site. This experiment has been repeated six times by generating six random and different sites, in each of which ten sections have been visited according to the order suggested by two approaches and an average has been calculated. One can notice that based on CASTA a tourist can visit ten locations in less time than those

sections suggested by the shortest path and shortest-with-NC approaches. This is because CASTA suggested an order of sections that is based on other factor, i.e. the contention level, than the distance on which solely the shortest path approach relays or the combination of distance and network connection quality adopted in shortest-with-NC approach. The more crowded the sections the more time is needed to complete a tour. By taking these two factors into account, CASTA apparently outperforms the shortest path way of selecting sections in a site.
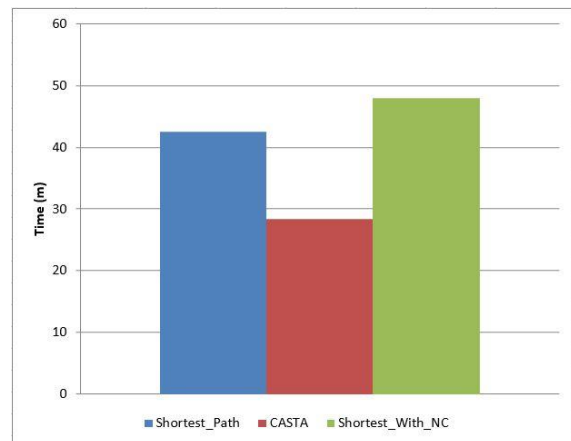

Figure 11. Average time to visit only ten sections in each site out of six.

5. CONCLUSION

Applying IOT tools would enhance the tourist experiences, particularly, in the context of archaeological tourism. Additionally, it will facilitate and support the efforts to protect and sustain the archaeological heritage. Thus, this study was designed to propose and assess the impact of a new approach, CASTA, of suggesting tourism destinations for mobile tourist based on their own preferences expressed in a message that is sent to control unit (CU). The CU resides in a cloud-centric IoT and has an access to various databases that are fed by information through smart city sensors which collect the relevant information.

Results of simulated experiments that have been conducted to evaluate CASTA in comparison with the shortest path and shortest-with-NC approaches have been presented and discussed. CASTA has been found to suggest more suitable sites in terms of less intra-site contention level and inter-site paths congestion level, even though it could be more remote than others given that paths to those sites are covered with quality wireless network connection. Moreover, since CASTA selects within each site a set of sections that are less crowded, more convenient, and accessible, it allows a tourist to have faster tour with much leisure than that suggested by shortest path and shortest-with-NC approaches.

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