IMPLEMENTING AN INTERNET OF EVERYTHING SYSTEM IN THE ARCHAEOLOGICAL AREA OF QUINTILI'S VILLA IN ANCIENT APPIA ROUTE PARK IN ROME

FABIO GARZIA
Safety & Security Engineering Group - DICMA, SAPIENZA – University of Rome, Italy
Wessex Institute of Technology, Southampton, UK
European Academy of Sciences and Arts, Salzburg, Austria

ABSTRACT

Archaeological areas represent, all over the world, significant cultural heritage sites that extend over vast areas requiring cultural heritage conservation and where it is necessary warranting visitors' security, safety, defence and provision of specific care to visitors with disabilities. In this paper, the author proposes a Smart Archaeological Area (IoE-SAA) system that could guarantee the proposed goals by means of integrated smart systems and innovative technology, such as Internet of Everything (IoE) in an efficient way. The chosen archaeological site where the system has been studied and designed is represented by the Quintili's villa, located in the ancient Appia Route Park in Rome, Italy. Advanced techniques such as Genetic Algorithms (GAs) have been used to optimize the distribution of proper multiservice poles (MPs) of the integrated system. The purpose of this paper is to illustrate a proper IoE based integrated technological system which ensures a reduction of final costs and an enhanced level of reliability and resilience of the system itself, taking into consideration the typical vincula and restrictions of the considered archaeological area.

Keywords: Internet of Everything, IoE, IoE integrated security system, IoE smart archaeological area, genetic algorithms based system design, drone for security, communication network security.

1 INTRODUCTION

Archaeological sites around the world represent significant cultural heritage and typically span wide surface areas drawing the interest of an ever-increasing population of visitors from across the globe. The conservation of such sites and the safety of their visitors are two main priorities in the management of such cultural heritage sites. Conservation aspects relate to maintaining several parameters related to the physical infrastructure. Safety aspects relate to the well-being of the visitors and their comfort as well as the usability aspects of facilities particularly for people with special needs, children and the elderly. In the present world, security of both infrastructure and crowd form a key aspect in the management of such sites. In this paper, the author proposes an innovative technological capability with an integrated approach [1]–[3], that includes Internet of Everything (IoE) [4]–[6], in an optimised manner. Such a system is defined by a Smart Archaeological Area (IoE-SAA) that could guarantee the proposed goals.

The chosen archaeological site where the system is studied and designed is represented by the Quintili's villa, located in the ancient Appia Route Park in Rome, Italy, whose extension is of about 24 hectares. To start with, a preliminary analysis of the site [7], is carried out in detail followed by a suitable safety and security risk analysis [8], [9], to identify all the threats, and the related risks to face and measures to reduce them by means of the design of an IoE based integrated system to achieve the proposed IoE-SAA system.

The technological solutions proposed have a need to evolve over time taking into consideration the performance of the sub systems. For this purpose, advanced techniques such as Genetic Algorithms (GAs) have been used to design the integrated security system

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that enable this very capability. In this way, it has been possible to design a full IoE based integrated technological system which ensures a reduction of final costs and an enhanced level of reliability and resilience of the system itself, taking into consideration the typical vincula and restrictions of the considered archaeological area. The specific design techniques are illustrated in the paper.

2 THE ARCHEOLOGICAL AREA OF QUINTILI'S VILLA IN ANCIENT APPIA ROUTE PARK IN ROME

The chosen archaeological site where the system is studied and designed is represented by the Quintili's villa, located in the ancient Appia Route Park in Rome, Italy, whose extension is of about 24 hectares. Some pictures of ancient Appia Route are shown in Fig. 1.

Appia Route was an ancient Roman route that connected Rome with Brindisi in Apulia (Brindisium in Latin) which represented one of the most important ports of that age where the ships for Greece and East left and arrived. Ancient Appia Route was considered by ancient Romans the queen of route for its considerable economic, military and cultural impact over the Roman emperor. It is universally considered one of the most important engineering work of the ancient world, seeing also its realization date (end of IV and begin of III century B.C.). Considerable parts of the route are still visible in Rome where it is possible to walk around them. The construction of the route started in 312 B.C. due to the will of the censor Appio Claudio Cieco (Appius Claudius Caecus in Latin), restoring and widening the already existing route that connected ancient Rome with the close hills, to reach Capua, close to Naples. Around mid III century B.C. it reached Benevento (Beneventum in Latin) and in the second half of III century B.C it reached Taranto (Tarentum in Latin). Finally, around 190 B.C. it reached Brindisi (Brindisium in Latin). The whole path from Rome to Brindisi is shown in Fig. 4.

In 1998, the regional park of ancient Appia Route was created with the purpose of preserving the wide archaeological area that extends from Rome till the base of the hill close to Rome. Some parts of the ancient route are still visible not only in the park but also in some zone of Lazio, Campania, Basilicata and Apulia regions. The ancient Appia Route is full of monuments and, in particular way, in the initial part within Rome. An important archaeological area is represented by Quintili's villa which belonged to the Quintili noble family of ancient Rome. It represents the largest and most magnificent residence in the Roman suburbs and dates to 151 A.D. It extends between the ancient Appia Route and the new Appia route that is currently used as a road for vehicles.

The most impressive construction nucleus is the one related to the Quintili family members and of their servitude: a circular building, a series of rooms, and the two large chapels of the 'calidarium' and 'frigidarium', fourteen meters high, with large windows and polychrome marbles (Fig. 2). Other interesting zones are represented by the entrance building (Fig. 3) and the 'Santa Maria Nova' area (Fig. 4).

Figure 1: Views of ancient Appia Route.

Figure 2: Views of Quintili's villa.

Figure 3: Views of entrance building and interiors of museum.

Figure 4: Santa Maria Nova area and path of ancient Appia Route from Rome to Brindisi.

3 THE INTERNET OF EVERYTHING SYSTEM

In this section, we consider the design aspects of the IoE-SAA sub-systems that provide safety, security and comfort aspects. In particular, this section deals with the design considerations of fault tolerant power supply and communications systems as well as surveillance technologies that form key sub-systems of the proposed IoE-SAA.

Firstly, the IoE system is studied and designed to:

1. Ensure the maximum level of protection to people and cultural heritage, both from safety and security point of view.
2. Ensure visiting and assistance services to visitors with special attention to visitors with special needs. From this point of view, thanks to the positioning / tracking capabilities of visitors through their mobile terminal where an app (privacy compliance) is installed, it is possible to know at any time where visitors are. In this

way, thanks to the app, it is possible to provide visiting / communication / positioning / tracking services useful in ordinary and emergency conditions.
3. Ensure an elevated level of easiness in using the system, utilizing local and remote sub-systems, through fixed or mobile terminals at any distance from the site, giving care to human factor and the psychological aspects [10], of both safety & security personnel and visitors.
4. Reduce as much as possible any adverse impact on the architecture and its aesthetics.
5. Reduce as much as possible the cost of maintenance and energy consumption.
6. Ensure the maximum level of reliability, resilience, flexibility and future expansion so that it is possible to add any time new IoE services, including safety & security services, aimed at realizing a smart archaeological area (IoE-SAA).

The above objectives are met through the design of an integrated IoE system that comprises of a local control room, mobile terminals for use by security management personnel and remote-control rooms distributed across the site, and several sub-systems and services to enable security, safety and any emergency management activities. Some of these services include the following:

1. Video surveillance; Access control; Intrusion detection; Future IoE devices, installations, etc.
2. Wireless networks used by security personnel to manage any critical situation and the related emergency, thanks to the positioning of their mobile terminals.
3. Wireless networks used by visitors, by means of an app to be installed on their mobile terminals before entering the site, to ensure IoE services such as: ordinary and emergency communications; multimedia services to ensure a greater usability of the site, like augmented reality (AR); localization to warrant a higher level of security / safety and of management of critical situations and statistical data regarding the most visited zones of the site, the permanence time, the most followed visiting routes, etc.
4. Any sort of monitoring (energy, maintenance, etc.).
5. Flying drones controlled by the system for security/safety and emergency management.

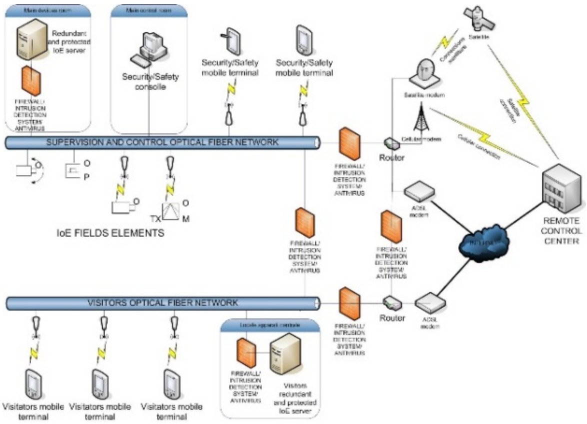

Figure 5: Architecture of the IoE system.

The architecture of the IoE system is shown in Fig. 5.

Reliable and resilient communication and electrical supply systems have been studied to face any critical event due to safety & security reasons.

The introduction of innovative technologies as part of the infrastructure can have a negative impact on the cultural heritage infrastructure as well reduce its aesthetic. To keep a minimum impact, significant efforts are made in the consideration of sub-systems such as using existing ducts for air-conditioning rather than designing new systems.

The IoE system is characterized by a distributed intelligence network and, for this reason, multiservice poles (MPs) which represent devices equipped with poles, were designed and studied ad-hoc for the considered site. They provide necessary functionalities, by means of on-board field devices and sensors field-elements such as Wi-Fi Access Points, wireless bridge, video cameras, etc. The distribution of the multiservice poles has been optimized using genetic algorithms (GAs) [11], to reduce as much as possible their numbers without exceeding the permissible number of installations in the site. The MPs must be reachable by electrical supply cables and optical fibre communication cables using, as much as possible, the existing cable ducts. The scheme of MPs is shown in Fig. 6 that illustrates the design of a fault-tolerant electrical power supply system. The main electrical cable is supplied from two diverse sources located at the opposite side of the site. In this way, if there is a malfunction of an electrical source, the other one ensures the power supply, guaranteeing a high reliability and resilience of electrical energy.

The MPs are equipped with an embedded back up electrical supply which uses rechargeable batteries. Further, the MPs are endowed by solar panels that contribute to charge the battery. In this way, the MPS can operate correctly even for long time in case malfunctioning of the main electrical supply.

MPs are connected to the main control room using a dedicated optical fibre connection. To increase the security level of the system, each MP uses two different optical fibres, one dedicated to the safety and security services and one dedicated to visitor's services. In this way, in case of cyber-attack [11], coming from the visitor's network, the safety and security network is protected since it is totally separated from the other network.

To ensure the maximum reliability and resilience of communications, the multiservice poles can also communicate using wireless bridge, where each MP is linked to the 2 nearest MPs. In this way, in case of malfunctioning of one MP, the communication can be recovered using the other MP, ensuring an elevated level of reliability entire system.

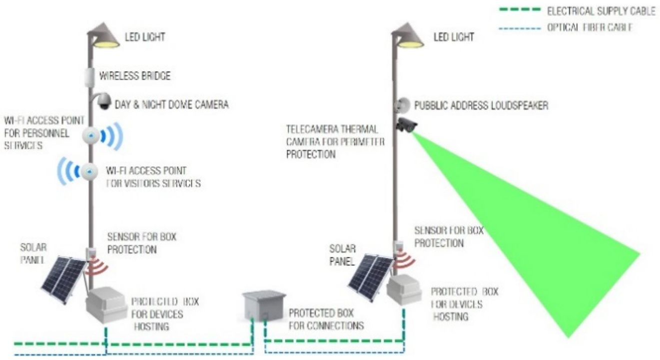

Figure 6: Simplified scheme of multipurpose pole and perimeter protection pole.

Thanks to the architecture of electrical and communication networks, the system can always operate in any critical condition due to safety and security reasons, guaranteeing its full functionalities.

The perimeter protection of the site is guaranteed by suitable perimeter poles (PPs) which are linked each other and linked with MPs so that they can work in a synergic way to reach the desired goals of the system.

Both MPs and PPs have been studied and designed for the specific site and are characterized by the following common features:

1. Reduced architectural and environmental impact.
2. Buried box located below the base of the MPs where all the devices are hosted ensuring that the box is protected against attacks.
3. Rechargeable batteries that allows the MPs work correctly even in the absence of main electrical supply for long time.
4. Solar panel capable of recharging the battery in the absence of the main electrical supply.
5. Low consumption and long working time LED light that can be switched on/off from the control room or from any enabled mobile terminal, or switched on/off automatically in case of intrusion alarm, so that the zone around the pole is immediately lighten to let reveal any intruder.

The multiservice poles are totally autonomous and can work correctly even in the absence of main electrical supply and optical fibre communication network.
The MPs are characterized by the following specific features:

1. Separated Wi-Fi access points to provide wireless services both to safety & security personnel and visitors, to ensure a separation between the two different networks, increasing the logical security [11], from attacks coming from the visitor's network.
2. Day and night high resolution dome camera capable of ensuring the right remote visibility in each area around the pole to the security personnel in the control room or on their mobile terminal, both locally and remotely. They can work in a coordinated way with the perimeter thermal camera, as it is shown in the following, so that they can immediately turn towards the alarmed zone of the perimeter to show the zone signalled by the thermal camera.
3. Wireless bridge linked to the two nearest MPs, so that a wireless redundant network capable of working in case of loss of the ground optical fibre network is made available.
4. Connection network with the closer perimeter poles passing through a cable duct is protected against attacks.

The MPs can operate in a totally autonomous way, providing video control and Wi-Fi services both to safety & security personnel and to visitors. They are distributed to ensure the full coverage of the site both from video cameras and Wi-Fi services.

The perimeter poles (PPs) are distributed along the perimeter. They are endowed by a smart thermal camera to signal any intrusion both day and night, analysing the image, creating an invisible protection visual fence. Their number is quite reduced since they can reach a long distance of coverage, reducing the architectural and environmental impact. Each PP is connected to the closest MP that ensures the PP to be constantly linked to the communication network and therefore to the entire IoE system. In case of alarm deriving from the smart thermal camera of a PP, the closest MP turns the dome camera towards the signalled zone, switching also on the LED light together with the PP, to provide clearly a correct vision of the zone even in the dark of the night.

The PPs are characterized by the following specific features:

1. Smart thermal camera that works in the far infrared range and can signal any intrusion both in the day or in the night, analysing on board the image and creating an invisible protection visual fence capable of discriminating people from animals or other moving objects such as bushes, leaves, etc.
2. Public address loudspeaker that can be used manually, to diffuse vocal message by the security personnel, both from the control rooms or mobile terminals, or predefined messages that are diffused automatically in case of unauthorized intrusion.
3. Connection network with the closest multipurpose poles passing through a cable duct protected against attacks.

4 THE GENETIC ALGORITHMS BASED TECHNIQUE FOR THE OPTIMAL DESIGN OF THE IOE SYSTEM

In this section, optimisation towards effective design that minimises any impact on the infrastructure and its aesthetic as well as the cost of maintenance of such systems is proposed.

Advanced techniques such as Genetic Algorithms (GAs) [10], have been used to design the integrated system, in particular way for multiservice poles. A general technique that uses GAs for the optimization of field elements has already been studied in [4], but the IoE system designed for the considered site using multiservice poles needs to create a specific GA for MPs optimal positioning.

A proper preliminary analysis has been carried out [7], to individuate the vincula of the area whereby it is possible to install the MPs without damaging any archaeological find.

Thus, the GA has a multi-objective optimisation function that aims to i) reduce the total number of MPs involved ii) provide suitable coverage of CCTV and Wi-Fi coverage area and iii) decrease the overall cost of the IoE system by their optimal placement.

MPs are characterized by circular coverage CCTV and Wi-Fi area. It is evident that the positioning of the MPs is influenced by the lesser coverage area between CCTV and Wi-Fi since it is desired the full coverage of both in the considered site.

Regarding CCTV coverage, it is well known that actual dome cameras can reach hundreds of meters with performing devices.

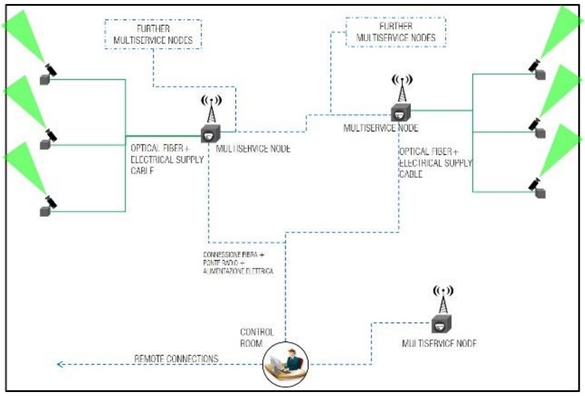

Figure 7: Scheme of the distribution of the system across the site.

For practical reasons, it is considered a maximum distance of 100 meters. Regarding Wi-Fi access points (APs), actual commercial devices can also reach hundreds of meters and even in this case, it is considered a maximum coverage distance of 200 meters.

To ensure the maximum flexibility, the coverage of the CCTV and that of the APs are treated as variables and independent such that the optimisation is specific to the individual MP.

The optimization problem must be translated into a GA to attain the wanted real solution in an effective and fast way.

The areas which must be covered by CCTV and Wi-Fi are attained through the preliminary analysis [7], of the archaeological area and they are stored in 2D geo – referenced and normalized array named CCTV and Wi-Fi$_{areas}$ respectively, whose resolution area is equal to 1 meter but that can be increased. Each element of the array (representing a cell of the considered area whose dimensions are 1 m x 1 m) that must be covered by CCTV and Wi-Fi is marked with a binary 1; otherwise, it is marked with a binary 0. Since in the most of real situations the considered areas are not characterized by a regular profile (square, circular, etc.), this kind of representation allows to design correctly the border of the considered coverage zones. A very similar structure is adopted for maintaining a record of the areas that are available for installation of multiservice poles stored in arrays named MP$_{areas}$.

It is now necessary to state the minimum number of multiservice poles (MPs) to cover the desired CCTV and Wi-Fi areas. From this point of view, the initial problem must be considered in the worst condition, that is using dome cameras or Wi-Fi APs whose coverage range is set at the minimum value. A real value is equal to 10 meters. Once defined the minimum coverage area $A_{min}^{CCTV\ Camera/Wi\text{-}Fi}$ of each camera/AP, it is possible to calculate the minimum number of CCTV cameras and Wi-Fi APs, and therefore of the related number of multiservice poles N_{min}^{MPs} to cover the whole requested areas with the worst coverage performances, which must be optimized and condensed by the GA, as:

$$N_{min}^{MPs} = \mathrm{round}\ (A_{CCTV/Wi\text{-}Fi} / A_{min}^{CCTV\ Camera/Wi\text{-}Fi}), \qquad (1)$$

where $A_{CCTV/Wi\text{-}Fi}$ is the total coverage area of CCTV and Wi-Fi which can be calculated by the array CCTV$_{areas}$.

The value attained by eqn (1) is for an ideal case where the entire area is available for MPs installation and if their coverage diagram is characterized by a regular shape (i.e. triangular, squared, etc.) which permits to guarantee a non-overlapped coverage. In real situation, the minimum number of MPs necessary to guarantee the wanted coverage of the considered archaeological area is far more than the value calculated by means of eq. (1), because of the imperfect matching of coverage diagrams of near field elements and due to the limitation of territory for placing MPs.

Therefore, given a certain area, an initial number of MPs is chosen as nN_{min}^{MPs} (n a parameter larger than 1) greater than the minimum number N_{min}^{MPs}. The GA carries out the task of optimising and reducing this number according to the availability of the installation areas to reach almost the minimum value of N_{min}^{MPs} or even less as a function of the distribution and shape of considered areas. It is also possible to select an initial number of MPs smaller than N_{min}^{MPs} considering that this does not permit the wished coverage of CTTV and Wi-Fi of the desired areas of the archaeological site.

Once the initial number nN_{min}^{MPs} of multipurpose poles are defined, it is now necessary to specify the parameters to be optimised for each of them namely: x coordinate of MP; y coordinate of pole; coverage area of CCTV dome camera; coverage range of AP.

Table 1: Features of the 4 genes.

GENE	Feature	Number of bits	Range (meters)
1	X coordinate of MP	14	0÷16.384
2	Y coordinate of MP	14	0÷16.384
3	Coverage distance of dome CCTV	7	0÷128
2	Coverage distance of Wi-Fi AP	8	0÷256

Let's discuss now the variability range of the parameters indicated above and the relative accuracy necessary to represent them in terms of binary strings.

Concerning the x and y coordinates, if a 1-meter resolution is considered and general area extension of an archaeological site (≈ 1–15 km), 14 bits are enough to represent a distance between 1 and 16.384 meters (i.e. ≈ 16 km). If it is necessary to consider a larger area, it is sufficient to add further bits, considering that each bit allows to double the considered distance. The dome cameras have been selected to reach a distance of about 100 metres. If a 1-meter resolution is considered, 7 bits are enough to represent a distance between 1 and 128 meters. Longer distances considerations are the same illustrated before. The APs have been selected to reach a distance of about 200 metres. If a 1-meter resolution is considered, 8 bits are enough to represent a distance between 1 and 256 meters. Longer distances considerations are the same illustrated before. Therefore, 4 genes are necessary to encode the installation multi-purpose poles parameters whose total length is equal to 43 bits. The features of the 4 genes are summarized in Table 1.

Each chromosome, or individual I, which represents a probable solution of the problem, is composed by a string representing all the $n^* N_{min}^{MPs}$ multipurpose poles and the related 4 parameters (whose total length is equal to 43 bits). Each chromosome is therefore characterized by a length equal to $43^* n^* N_{min}^{MPs}$ bits.

It is now necessary to define the fitness function f. This function must consider all the desired optimization goals, to reduce, as much as possible, the architectural impact on the archaeological area and the related cost of the system, which are represented by: coverage of the desired CCTV_{areas} and $\mathrm{Wi\text{-}Fi}_{areas}$ with the minimum number of cameras and APs; absence or minimum value of overlapping of coverage diagrams of CCTV cameras and APs; position of multipurpose poles only in the allowed zones.

The considered fitness function of the generic individual I, can be expressed as:

$$f(I)=\alpha\,\mathrm{CCTV}_{\text{coverage area}}(I)/\mathrm{CCTV}_{\text{desired coverage area}} - \beta\,\mathrm{CCTV}_{\text{overlapping area}}(I)/\mathrm{CCTV}_{\text{desired coverage area}} + \gamma\,\text{Wi-Fi}_{\text{coverage area}}(I)/\,\text{Wi-Fi}_{\text{desired coverage area}} - \delta\,\text{Wi-Fi}_{\text{overlapping area}}(I)/\,\text{Wi-Fi}_{\text{desired coverage area}} - \varepsilon\,N^{MPs}(I)/N_{min}^{MPs}. \qquad (2)$$

The first term of fitness function, weighted by a parameter α, variable between 0 and 1, considers the ratio between the coverage area of the all CCTV dome cameras of the individual I and the desired CCTV coverage area. If it reaches a value equal to 1, it means that the individual I can guarantee the full CCTV coverage of the desired area.

The second term of fitness function, weighted by a parameter β, variable between 0 and 1, considers the ratio between the overlapping area of all CCTV cameras of the individual I and the entire desired CCTV coverage area. If it reaches a value equal to 0, it means that the individual I can guarantee the full CCTV coverage of the desired area without any overlapping of the coverage area of each dome camera.

The third term of fitness function, weighted by a parameter γ, variable between 0 and 1, considers the ratio between the coverage area of the all Wi-Fi APs of the individual I and the desired Wi-Fi coverage area. If it reaches a value equal to 1, it means that the individual I can guarantee the full Wi-Fi coverage of the desired area.

The fourth term of fitness function, weighted by a parameter δ, variable between 0 and 1, considers the ratio between the overlapping area of all Wi-Fi APs of the individual I and the desired Wi-Fi coverage area. If it reaches a value equal to 0, it means that the individual I can guarantee the full Wi-Fi coverage of the desired area without any overlapping of the coverage area of each AP.

The fifth term of fitness function, weighted by a parameter ε, variable between 0 and 1, considers the ratio between the number of new multipurpose poles of the individual I and the total number of new multipurpose poles initially planned. If it reaches a value equal to 1, it means that the individual I uses of the all the new poles initially over-planned, not reducing the architectural impact on the archaeological area and the related cost of the system. In real cases, it is lesser than one since the GA can reduce the number of initial new MPs, by means of the optimal distribution of them, reducing the architectural impact on the archaeological area and the related cost of the system.

In Eqn.(2), some of the terms contribute negatively to the optimisation function and others positively to the same function. Accordingly, a positive (+) or negative (-) sign is associated with the corresponding terms.

Before starting, the GA does an initial and restraining check to verify if from the closer distance between each nearest multipurpose pole installation area (which can be derived from the MP_{areas} array) and each nearest CCTV coverage area (which can be derived from the $CCTV_{areas}$ array) it is possible to cover the whole nearest area using a camera whose coverage area allows the maximum performance. If this is not possible, an appropriate alert is generated so that it is possible for the human system designer to seek another solution to solve a problem (extending, for example, in this critical situation the multiservice poles installation area). If this preliminary test is not carried out, the GA could end up working indefinitely. This external bias is required because the stop criterion cannot be determined without discovering the optimal solution. The same preliminary check is done on the Wi-Fi coverage areas.

The poles' permissible position in the zones are determined through the genetic operations of reproduction, crossing and mutation. The values in the array MP_{areas} contains the coordinates of the new poles considered and encoded in binary format as a chromosome. These values are checked to see if they hold a 0 (not permitted to install a pole) or 1 (permitted). Only the chromosomes corresponding to a 1 are retained as survival of fitness measure of the GA.

Since the initial population is generated randomly, generally there is a part of it which is deleted at the beginning, but after the first few iterations more fitting individuals are generated and it is not necessary to delete any of them. Once recombined and mutated the population, the fitness function of the population is again calculated with the same criteria illustrated above, considering only fitting individuals. The converge test is made controlling if the difference between the mean value of fitness functions of the valid individuals belonging to the actual generation and the mean values of the last N_G generations is lesser than a certain percentage value p_{stop} selectable.

The GA has been tested on more than 700 real and random CCTV coverage areas, Wi-Fi areas, new installation poles areas to derive general mean results valid for any kind of similar

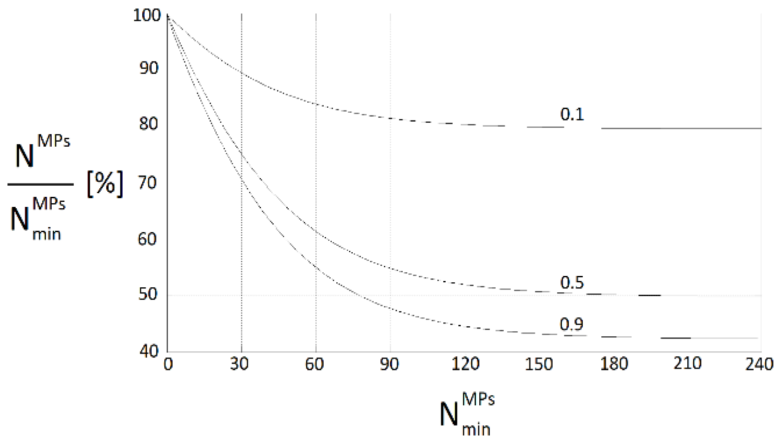

Figure 8: Ratio between the final number of multipurpose poles attained after GA optimization and the initial number of multipurpose poles Nmin MPs (related to the extension of the desired CCTV/Wi-Fi coverage areas) as a function of the initial number of multipurpose poles $N_{min}{}^{MPs}$, for different values of the ratio between the total area of MP_{areas} and the total area of the archaeological site.

archaeological areas. All the results, achieved with a quite rapid converge, shown in the following, are obtained with converge test parameters N_G and p_{stop} equal to 25 and 0.3 respectively. Due to the huge quantity of final data attained and to the number of results which can be extracted from this huge quantity of final data, only the most noteworthy results are shown in the following. An important parameter to be considered to derive significant data is represented by the ratio between the total area of MP_{areas} and the total area of the archaeological site.

This parameter provides an idea about the availability for installing multipurpose poles, and therefore about the degree of freedom of GA to performs its optimization achievement.

If this ratio is low (0.1 for example), it signifies that a reduced amount of areas, with the respect to total area of the site, is available for multipurpose poles installation and, therefore, that GA cannot achieves, in the best way, it's optimization action. If this ratio is great (0.9 for example), it signifies that a huge amount of areas, with the respect to total area of the site, is available for multipurpose poles installation and, therefore, that GA can achieve, in the best way, it's optimization performances.

From Fig. 8 it is possible to see that in all cases the final values of multipurpose poles (N^{MPs}) reduces with the increase of the initial number of multipurpose poles ($N_{min}{}^{NPs}$), related to the increase of CCTV/Wi-Fi areas to be covered, reducing the architectural impact on the archaeological site and the cost of the system. This reduction is more rapid and approaches lower asymptotic values for a great value (0.9) of the ratio between the total area of MP_{areas} and the total area of the archaeological site while it is less rapid and reaches greater asymptotic values for low value (0.1) of the ratio between the total area of MP_{areas} and the total area of the archaeological site. This behaviour can be explained with the degree of freedom which this last important ratio allows to the GA to achieve its optimization goal.

5 CONCLUSIONS

An IoE based integrated technological system of the archaeological site of Quintili's villa located in the ancient Appia Route Park in Rome, Italy has been studied, designed and illustrated in this paper. It ensures visitors safety & security, cultural heritage preservation/protection and great usability for visitors with particular reference to visitors with disabilities, considering the typical vincula and restrictions of the archaeological sites. Advanced techniques such as Genetic Algorithms (GAs) have been used to optimize the distribution of proper multiservice poles (MPs) of the integrated system, reducing the final realization cost, as demonstrated by the obtained results which have been illustrated.

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