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THE INFOSTATION PARADIGM – PAST, PRESENT AND FUTURE DEVELOPMENTS

Ivan Ganchev, Stanimir Stoyanov, Damien Meere,
Ivan Dimitrov, Máirtín O'Droma

Abstract. *This paper details the InfoStation (IS) paradigm, upon which modern mLearning systems [1] could be successfully built. The origins of this paradigm are discussed by identifying the reasons for the paradigm's inception and how this design approach was intended to aid the delivery of wireless data services. The state-of-the-art of the IS-based infrastructures, designed to facilitate the delivery of mobile services (mServices) within an educational institution area is then presented. The IS network architecture is described detailing each of the components which comprise the three tiers. Also discussed is a high-level view of the process through which each of the main system components collaborates in order to facilitate the delivery of various mServices. Future directions for research and development (R&D) in this area are set up at the end.*

Keywords: InfoStations, mServices, anytime-anywhere-anyhow access, request globalisation, deployment map

1. INTRODUCTION

The continuing evolution of ICT and mobile technologies presents a means to facilitate ubiquitous teaching and learning (T&L) environments, providing learners with access to an enhanced learning experience. From the very beginning, a means was sought to efficiently incorporate mobile technologies to a much greater degree within educational environments, and as such facilitate access to services designed to complement and enhance the learning experience of both educators and learners alike. From a technological standpoint, effectively achieving the "anytime-anywhere-anyhow" delivery [2, 3] of mobile services (mServices) became a major concern. However, many modern communications systems still strive to achieve ubiquitous coverage.

It wasn't until the advent of the second generation (2G) of cellular systems in the 1990's, that the use of mobile phones truly exploded into the public consciousness. 2G communications, primarily based on the Global System for Mobile Communications (GSM) [4], brought about a number of improvements over its predecessors, such as the utilisation of digital signalling as opposed to analog. But most notably, from the public's perspective, it saw the introduction of digital data services for mobile users such as the Short Message Service (SMS). The introduction of these services served to introduce the public to the use of data service in their everyday lives, and as their popularity grew, so did the thirst for newer and more pervasive services. However, 2G infrastructures were built to cater for voice and slow data transmission. To address the need for faster data transmission and more advanced data services, evolutionary steps were taken to enhance the 2G network. For example General Packet Radio Service (GPRS) [5], which can be considered 2.5G, saw the introduction of the Multimedia Messaging Service (MMS), as well as offering communication services such as email and Internet access. This 2.5G technology saw the introduction of packet-switching which allowed the utilization of the network only when a transaction was required, as opposed to maintaining the connection in a session-like manner. 2G technologies were enhanced further, approaching what we now consider third-generation (3G) technologies with the development of 'Enhanced Data rates for GSM Evolution' (EDGE). This enabled the transmission of even higher data rates. Of course before 3G, 3.5G (LTE) and most recently 4G (LTE Advanced) [6, 7] technologies became as prevalent as they are today, offering high-speed wireless broadband over great distances, many projects and initiatives throughout the world, both within academia and industry, sought to find newer and more efficient and innovative methods of delivering wireless data services to mobile users. The InfoStation (IS) initiative was one such project.

2. ORIGINAL INFOSTATION CONCEPT

The IS paradigm was originally proposed to provide "many-time, many-where" wireless data services. The original IS architecture, proposed by researchers at the Wireless Information Network Laboratory (WINLAB) at Rutgers University [8], was suggested as a viable alternative to cellular WAN, addressing shortcomings in the delivery of wireless information services within 2G cellular networks, such as low bandwidth and bit rate, battery limitations, cost, etc. 2G systems were originally designed to provide ubiquitous coverage for voice transmission. These systems were designed to provide adequate signal-to-interference ratio (SIR) in most locations [9]. As a result, many locations (typically at the core of each cell) had a channel quality that exceeded these specified criteria, sometimes by a significant margin. The IS initiative was proposed to capture this excess capacity in order to offer increased data rates, while using the same channel bandwidth. While this of course was unnecessary for voice transmission, this would facilitate the delivery of high-bit-rate services within these core locations. Figure 1 illustrates the core areas within which the ISs could deliver large files quickly with high spectral efficiency and low cost.

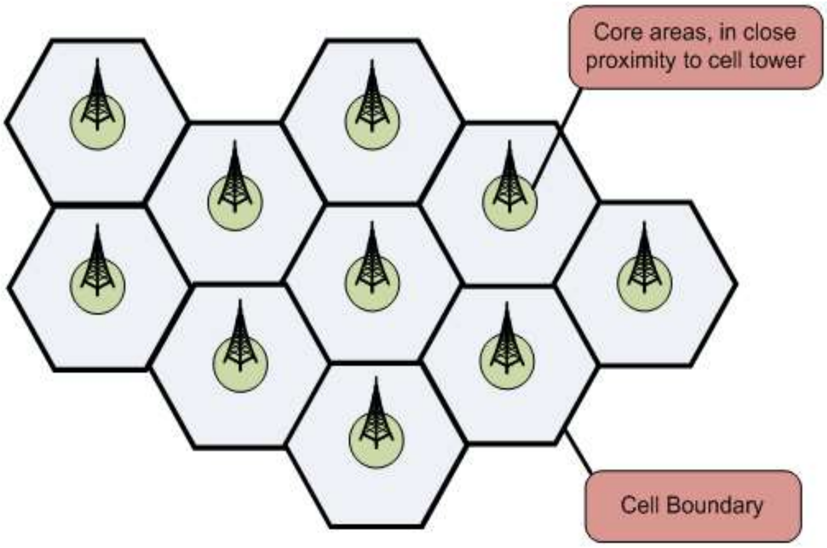

Figure 1. Early InfoStation system architecture (adapted from [10])

It is around this idea that the IS paradigm arose. As opposed to facilitating ubiquitous coverage, within these geographically intermittent pockets, ISs could offer high-bit-rate connectivity to broadband data- and network services, since data, as compared to voice, can often tolerate delay inherent to intermittent transmission [11]. These pockets of connectivity could be placed within informational environments as independent access points to the Internet, or indeed, they could be organised into clusters having a common server operate as a gateway to the Internet. The distributed, isolated nature and internal networking structure of ISs, enabled them to operate as standalone wireless data sources in remote locations, delivering huge amounts of data during one transmission burst [12], and as such, satisfy the needs of many data-intensive applications, facilitating a class of drive-by services [13].

Essentially the IS concept trades delay for improved network capacity, with users experiencing fast data rates at the expense of intermittent network connectivity [14]. Within the IS paradigm, the core idea was that as a user passed within range of the discontinuous coverage area, his/her terminal was quickly filled with information at a high data rate. The information transmitted could consist of messaging or location information, again depending on the informational environment. As highlighted in [8, 9], the pockets of high-bandwidth connectivity could be spaced along roadways, positioned at building entrances, at airports and in other predictable, accessible or high-profile locations. According to [9], these ISs are relatively simple devices and might be organized in different, ways, depending on the deployment environment as illustrated in Figure 2. For example, individual ISs could be positioned on road sides and streets, in airports or educational institutions, and depending on the environment, could behave and operate in a number of ways. Whether acting as ‘isolated’ cellular nodes, or as part of geographic cluster, or 'campus' environment, ISs could function independently, providing specialized gateways to the Internet/Intranet, as well as to remote servers for information and message retrieval.

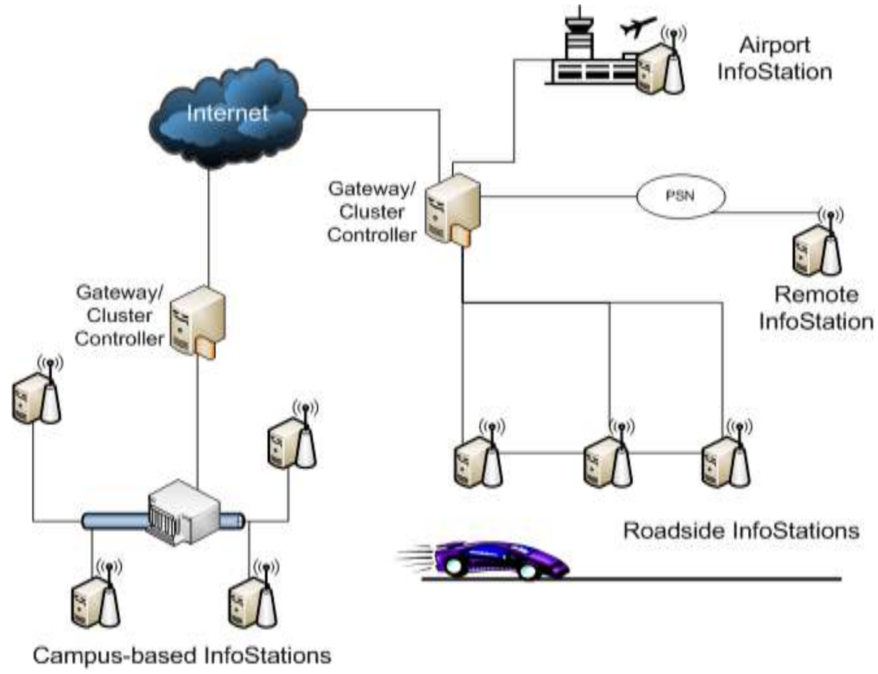

Figure 2. Varying InfoStation deployment environments

During this early research, it was posited that ISs could be integrated into, and coordinated with, ubiquitous low-bit-rate services, facilitating caching and opportunistic delivery of files and in essence providing a means to boost the capability of wide-area service provision within close proximities. As discussed in [15-17], according to the deployment environment of the IS, three types of user mobility scenarios could be considered: "sit-through" scenario, where stationary users, such as those within a library or classroom access the system; the "walk-through" scenario, where users move slowly within range of the IS; and the "drive-through" scenario, where users move at high speed through the coverage area of the ISs.

With the advent of 3G cellular networks, the application area of ISs within countries with developed infrastructures diminishes greatly. However, within developing nations, and indeed within many informational environments, the IS concept can provide valuable lessons for the delivery of mServices. For instance, the system detailed in the next section seeks to build on the work undertaken as part of previous IS projects, in order to deliver localised, contextualised and personalised mServices within particular application domains. The target is the deployment of supplementary communication and mLearning services within educational institutions. However, this is not the limitation of this type of infrastructure, and could indeed be used to enhance a wide variety of informational environments (beyond educational institutions), enabling service developers to facilitate enhanced informational experiences to a multitude of system users.

3. INFOSTATIONS STATE-OF-THE-ART

The current IS development has reached a state, where an IS-based system architecture enables registered users to access a range of mServices through a distributed network of intelligent wireless nodes (ISs), situated at key locations (library, faculties, lecture theatres, cafeteria, restaurants, parking areas, etc.) throughout a particular application domain, e.g. a university/school campus. These ISs can essentially be thought of as portals through which the user mobile devices (MDs) can communicate with a wide variety of services. Indeed, in its current state, the IS paradigm itself can be considered akin to the extended wireless Internet [18], where the mobile clients interact directly with the web service providers. In the case of an IS-based system, the local service provider role is taken on by the IS deployed within informational environments. From a technological standpoint, the aim of these systems is to facilitate "anytime-anywhere-anyhow" access [2, 3] to learning objects, which can be adapted to suit both the preferences and context of a particular user, as well as the MD utilised to access the service content. This type of systems provides an ideal opportunity for the facilitation of a mLearning environment of learners, which can be used to effectively enhance traditional practices, and precipitate an educational system which will take on a more familiar appearance to learners born of a digital age. Such architecture can also be utilised as a platform for the delivery of other supplementary communications services supporting the mLearning process. The importance of communication between learners and educators cannot be underestimated, and the effective deployment of such systems can serve to greatly simplify this process, and promote more open educational practices.

While IS systems have, in the past, been designed with cellular WAN technologies in mind, the contemporary IS-based systems seek to incorporate other widely available wireless communications technologies in order to provide service access to a wide range of MDs. In particular, wireless communications technologies such as:

- IEEE 802.11 WLAN (WiFi),
- IEEE 802.16 WMAN (WiMAX), and
- IEEE 802.15 WPAN (Bluetooth)

are particularly useful (Figure 3).

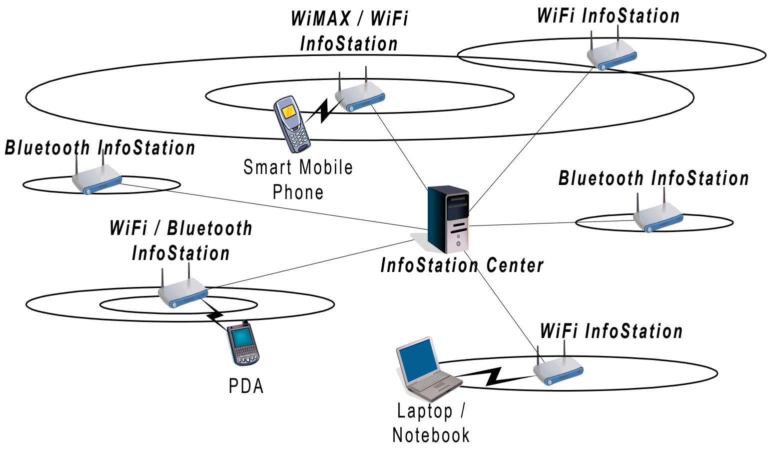

Figure 3. Multiple communication mechanism support by InfoStations

Of course the placement of this array of wireless portals at key points throughout a university/school campus also has a bearing on which services are accessible. At certain locations, the ISs may be specialized to provide specific location-based services. This is an idea which is particularly applicable to educational institutions. mLearning services can be offered through ISs operating within lecture halls facilitating the enhancement and blending of the T&L experience of both learners and educators. Such systems also demonstrate great potential for deployment within libraries or within specific departmental areas within an institution, supporting services tailored to that environment.

The contemporary IS-based systems have a 3-tier structure. Services are generally concentrated in specific areas on the application domain. This offers the opportunity to facilitate targeted services based on the location in which an IS is positioned. The IS-based systems are organized in such a way that if the local IS cannot fully satisfy the user service request, the request is forwarded to the InfoStation Centre (ISC). Each mService is delivered in the most appropriate, quickest and cheapest way to each user according to his/her current individual location and MD's capabilities [19].

The first tier encompasses the user MDs. The users' interactions with the system are facilitated by an intelligent agent on board the device, which acts as Personal Assistant (PA). By utilizing these intelligent agents, the users may access the catalogue of services on a variety of devices with a wide range of capabilities. MDs such as traditional cell phones, smartphones, tablets and laptops may all house PAs. Due to the geographically intermittent nature of the connection to the ISs, it is necessary for the PAs to function autonomously [20, 21] to satisfy the user service requests, whether in or out of contact range with other agents (installed on the ISs and/or ISC). As a service session may be split between a number of these isolated ISs, the PA may make a service request while within the range of an IS, and then pass out of the coverage area. During the time the user is out of IS range, the PA must continue to function autonomously, enabling the user to continue using the service. It is important that the transition between ISs be transparent to the users, and that discernible loss of service access is limited. The agent autonomy allows for the most efficient utilisation of the IS high-rate intermittent coverage. Once the MD enters another IS cell, the user service profile will be updated and synchronised to reflect any work completed by that particular user whilst out of range of the IS network (e.g. completion of mTests, transmission of messages, etc.).

Another service scenario addressed is that of the possibility for the user beginning a service session on one device and finishing on another. This scenario may arise if a user begins accessing a service on a device with a low range of capabilities (e.g. basic cell phone), and may, for example, only be capable of accessing a service in a purely textual format. However, the user may switch device mid-session and begin utilising the service on a device with much greater level of resources (e.g. smartphone, laptop). In this case the user would have access to a full multimedia version of the service. This highlights the need for the dynamic contextualisation of services to suit both the users and the accessing devices. Due to the massive variation in devices and device capabilities, it is essential that all services be capable of adaptation, and as such be completely independent of whatever operating environment they may be accessed from.

In delivery of each service, the content must be adapted and customised to the capabilities and constraints (i.e. hardware, software attributes, etc.) associated with each class of user devices. The screen size, audio and video capabilities in particular have a huge bearing on how a service is ultimately to be delivered and presented to a user. The adaptation and contextualisation address the need for these IS-based systems to facilitate a wide variety of devices with varying capabilities, while still delivering the ‘best’ Quality of Service (QoS). It is the task of the PA to gather the capability and preference information from the user device, and once the PA has conveyed this information, the IS can adapt and deliver particular service content in an optimal format for that operating environment.

The technical characteristics of the MD are not the only attributes which have a bearing on the adaptation procedures. The PA must fulfil the role specified in its title and aid the user in accessing services and service content in a format most preferable to the user. The PA allows users to specify various attributes relating to themselves and of course to their own personal preferences. Attributes relating to their department, classes and even their role from an educational standpoint (i.e. educator or learner) must all be taken into account when delivering the services. This type of personalisation is essential within educational institutions, as learners within various cohorts will only want access to services which are applicable to them. As such, adaptation procedures must also cater for a level of personalisation in preparing service content for delivery.

The second tier of the contemporary IS-based systems consists of a distributed network of ISs deployed at key locations, e.g. throughout an educational institution. The ISs facilitate network access / connectivity for mobile users with wireless capable devices, and as such, mobile access to various mServices through high-speed, geographically intermittent connections. It is essential to the functionality of these ISs that they be equipped to support multiple communications mechanisms in order to provide sufficient access for a great range of MDs.

The ISs accept profile information and service requests from the user MDs, and perform Authentication, Authorisation and Accounting (AAA) procedures to ensure various access rights to the services. If an IS finds itself unable to perform AAA on a particular user, having no previous record of that user in its profile repository, it may forward the user's profile information on to the ISC for further processing. The IS utilises information gleaned from user profiles and device capabilities to draw together a list of available, relevant services which may be forwarded on to the PA.

On receipt of a user service request from a PA, the IS examines its service repository for the latest, most up-to-date version of the service content. If needs be, it may request an update of the service content from the ISC. It is within the IS that the service customisation and adaptation procedures are undertaken, according to the capability and preference information detailed by the PA. In addition, the ISs perform urgent messages downloading, synchronisation of off-line eLearning process with on-line mLearning system (e.g. tracking the learner's progress, sending off-line questions to educators/librarians, receiving their answers, sending other relevant off-line information, i.e. test scores, time spent on task, etc.) [22, 23]. The ISs pass (in background mode) all synchronisation and updating information between the ISC and MDs, to ensure that all information throughout the system, from the core to the peripheries, is consistent.

The third tier is the ISC that stands at the core of the IS-based architectures. The ISC is concerned with the general service creation, deployment, operation, maintenance, control, and execution. In addition, there are some common support functions that each service requires when initially created, for example device management, profile management, service catalogue, etc. [19]. Another important function of the ISC is the control of information between the ISs, in particular the updating and synchronisation of information. The ISC also maintains a repository of up-to-date profiles information relating to both users and services alike. Any changes made by the individual user to his/her own user profile and/or service profile are forwarded on from the MD, through the IS (which caches its own copy of the profile) and then on to the ISC, where the repository is updated. These updates can then be disseminated throughout the system. By using these profiles in an educational environment, educators can monitor the progress of learners, keep track of learners test scores, and monitor any possible problem areas for each learner, ensuring a more efficient and meaningful learning experience. For this reason, it is essential that these profiles be maintained and synchronised across the entire system. The user profiles also contain information about the user's location and the devices they are currently utilising, which allows for more efficient and flexible delivery of the mServices. Service profiles provide information about service capabilities, i.e. advertising what services can do. The ISC also houses the Business Support Domain with a number of components relating to the charging and billing of users, User Relationship Management (URM), Resource Planning (RP), and AAA. The URM entails all aspects of the interactions that a service has with users, whereas the RP is a business management system, which integrates all facets of the business side of this service provision, taking into account various details [19].

4. FUTURE DIRECTIONS FOR INFOSTATIONS R&D

As pointed above, in some cases the user requests for particular services cannot be satisfied fully by the local IS due to resource deficit (e.g. when information needed to satisfy the service request is unavailable on this IS). In these cases, the service provision must be globalised in a manner involving other ISs (through ISC). The need for globalisation depends on the manner in which resources are deployed on the IS network nodes during the system initialisation. Given that each globalisation involves extra overhead, the problem is to find such deployment, which minimises the number of globalisations. The definitions of the main notions related to request globalisation are given below:

- *Request* – an information sent by a user to the IS-based system, which is structured accordingly to the access rules and evokes a corresponding reaction by the system. The request could be satisfied either by the local node (IS) where the user currently is located, or by another IS(s). In the latter case, the request must be globalised in order to be satisfied.
- *Information Resource* – a software component, which could be activated and used for processing of requests sent to the system. Resources can be *active* (e.g. software agents, mServices, etc.) or *passive* (e.g. databases, data structures, etc.). During the regular request processing, some interactions may occur between the information resources.
- *Local Node* – the local IS, which has received the original request and within the service area of which the user is currently located.
- *Global Node* – another IS, not the local node, which could be used for satisfying the request.
- *Request Globalisation (RG)* – the process of involvement of a global node in the execution/satisfaction of a request.
- *Deployment Map* – a map of deployment of information resources throughout the IS-based network.
- *Optimal Deployment Map* – the deployment map resulting in a minimum number of request globalisations.

In order to achieve high efficiency in the functioning of such systems, the execution of requests must be accomplished on the relevant local nodes as much as possible, i.e. by using only the information resources of the local nodes, which have received the original requests. This is a kind of an optimisation task related to the way in which resources are deployed on the network nodes in order to minimise the number of RGs during requests execution. Key problems related to the development of the possible formal RG model are treated in [21]. The model could be used for a subsequent definition of the task for finding the optimal deployment of information resources on the IS network.

5. CONCLUSION

Within this paper, the InfoStation (IS) paradigm, upon which modern mLearning systems could be built, has been discussed, by identifying the reasons for the paradigm inception and discussing how this design approach was intended to aid the enhanced delivery of mServices. A contemporary IS-based infrastructure, designed to facilitate the delivery of mLearning services within an educational institution area has been detailed, illustrating its composition, and detailing each of the components comprising the three tiers of the structure. A high-level view of the process, through which each of the main system components collaborates in order to facilitate the delivery of various mLearning and supplementary communications services, has been presented. Also highlighted was the necessity for support of multiple communications mechanisms in effective delivery of mServices. Finally, R&D directions in relation to request globalisation issues have been outlined for future study and work.

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Ivan Ganchev, Damien Meere,
Máirtín O'Droma
University of Limerick,
Limerick, Ireland
E-mail: Ivan.Ganchev@ul.ie,
Damien.Meere@ul.ie,
Mairtin.ODroma@ul.ie

Stanimir Stoyanov, Ivan Dimitrov
University of Plovdiv,
Plovdiv, Bulgaria
E-mail: stani@uni-plovdiv.bg,
ivandimitrov@uni-plovdiv.bg