# Introducing Anonymous Real-Time Mobile Community Services

E. Adamopoulou, K. Demestichas, C. Dessiniotis, J. Markoulidakis, and M. Theologou

*Abstract*—**This paper analyzes the concept of Anonymous Real-Time Mobile Community (ART-MC) services, which enables the real-time collection of information residing in a community of mobile terminals, which can then be processed and delivered to a service requesting terminal. An example application is the provision of real-time information concerning road-traffic conditions, based on the location and velocity of mobile terminals. The ART-MC concept requires the deployment of an appropriate software client at the terminal side, as well as the deployment of an ART-MC Server at the network side. The proposed architecture is presented and explained in detail. Anonymity and privacy issues are addressed, and an extensive analysis regarding scalability is given. Finally, additional example applications of the ART-MC concept are listed.**

*Index Terms*—**Anonymity, Mobile Applications, Mobile Communities, Service Enabling**

## I. Introduction

In the current mobile telecommunications environment, mobile terminals perform a variety of network-related and application-related functions, mainly acting as clients/ recipients of services. In addition, their capabilities in terms of storage capacity, processing power, as well as connectivity options (GSM/GPRS, UMTS, WLAN, etc.), are constantly evolving. Taking advantage of this context, along with the increased mobile terminals' penetration in the market, this paper introduces and further elaborates on an innovative concept, according to which mobile terminals (end-users) may act not only as service requestors but also as members of a community that contributes to the service delivery and content production. In particular, the concept of *Anonymous Real-Time Mobile Community (ART-MC) services* exploits the ability of the network to retrieve in real time useful data from multiple mobile terminals. The collected data are impersonalized and can be generated either at the time of the request, or at an earlier time (in which case they remain stored in the terminal). Subsequently, the gathered data are processed, in order to compose the target information or content element which will be delivered to the requesting terminal.

Our vision is to build an open framework based on the ART-MC concept that will enable the provision of various types of innovative services. Example services include: Real Time Vehicular Traffic Conditions, Clubbing/Restaurant Information, File Sharing, Environmental Applications, Mobile Multiplayer Gaming, Emergency Services, Socializing Applications, and others. These examples are further discussed in Section V.

The remainder of this paper is structured as follows: Section II discusses the state-of-the-art landscape and compares it to the ART-MC concept. Section III analyzes the proposed ART-MC architecture. Section IV deals with important research topics, namely anonymity/privacy and scalability issues. Section V outlines representative example applications, while Section VI concludes the paper.

## II. State of the Art

The concept of community-based services originates from the world of Internet. Example services include: Bulletin Boards, Chat-rooms, Instant Messaging, and Web Portals/Weblogs. To some extent, the concept of communities has also entered the world of mobile communications. For instance:

- Some Weblogs provide users the ability to post content through MMS or email messages [1]-[3].
- The Wavespotter solution [4], provided by Wavemarket, is based on a Java (J2ME MIDP 2.0) client that lets users publish location-stamped information on a Web server. It also enables tracking of friends and family. MMS is used to send graphics and images from the client application.

Mobile community-based services have also attracted notable research attention in the recent years. The COSMOS project [5] was an initiative to investigate the deployment of Community Online Services and Mobile Solutions, along with their social acceptance. In the context of this project, virtual community members are allowed to communicate or interact under the appropriate circumstances. On the other hand, issues related to the content creation and the exploitation of data available at the terminals were not extensively examined. Service creation for mobile communities has also been a subject of study in the DBGlobe project [6]-[7]. The DBGlobe

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project's goal is to develop a data management system for modeling, indexing and querying data hosted by distributed, autonomous mobile peers, by employing a service-oriented approach.

The ART-MC concept comes as a valuable extension to the state-of-the-art in the area of mobile community-based services. As opposed to existing approaches, the ART-MC concept introduces the following innovative features: *(i)* Ability of automatic (as opposed to manual) data collection and uploading; *(ii)* Instantaneous formulation of the group of terminals that should be queried; *(iii)* Real-time processing of the collected data; *(iv)* Anonymity and privacy of both the service requestor and the service enablers (community of queried terminals); and *(v)* Provision of various, possibly diverse, services under a common umbrella.

## III. Architecture

### A. Generic Architecture

In this section, the proposed ART-MC architecture is presented and analyzed. For the implementation of the ART-MC concept, no modifications in the existing Radio Access and Core networks are required. As depicted in Fig. 1, the ART-MC concept requires the deployment of an ART-MC Terminal Client at the terminal-side, and an ART-MC Server at the network-side. These two components act as an underlying service enabling technology that facilitates the collection of information and the deployment of a multitude of ART-MC services. Third-party Application Servers implement each application's logic.

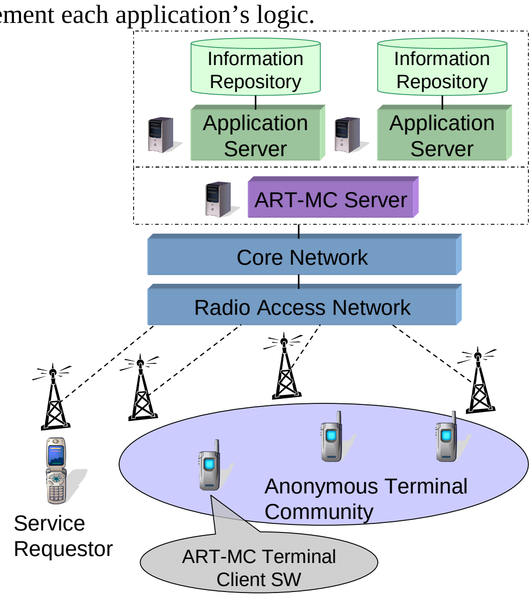


Fig. 1. ART-MC architecture

### B. Communication Flow

In a typical communication flow, four entities take part: the service requesting terminal (Service Requestor), an Application Server, the ART-MC Server, and the Anonymous Community of mobile terminals. Initially, as depicted in Fig. 2, the requesting terminal opens a service layer session with an Application Server and requests a service. Subsequently, the Application Server requests from the ART-MC Server to issue an appropriate query for impersonalized information. This communication follows the web services paradigm, over secure HTTPS connections. The ART-MC Server processes this request, in order to identify the target anonymous mobile community and form the appropriate query towards the members of this community. The query is then issued, either using a point-to-point SMS or WAP-push message, or using cell broadcast. The ART-MC Terminal Client of the queried mobile terminals handles the incoming query, by retrieving the requested local parameters and relaying them back to the ART-MC Server. The data upload process is carried out either through SMS or by opening a short data session (over GPRS, UMTS, or WiFi – whichever is available at the time). The ART-MC Server then encapsulates the collected data in a standard format and transmits the results to the corresponding Application Server. The Application Server exploits the received data, in order to produce the information that was requested by the end-user. Finally, it delivers the information produced.

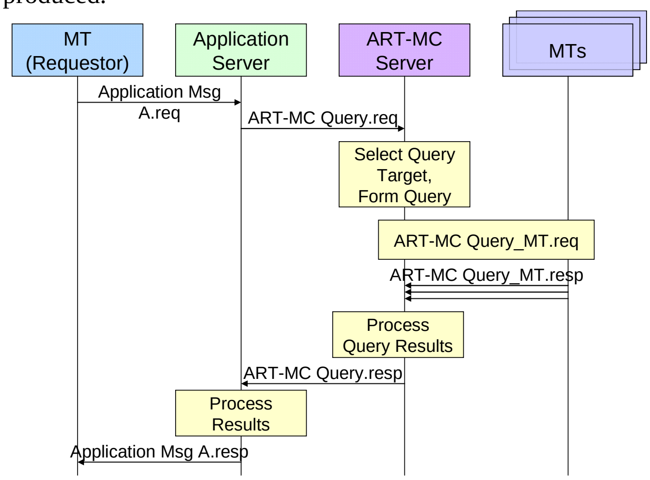


Fig. 2. ART-MC communication flow

### C. ART-MC Terminal Client Functional Architecture

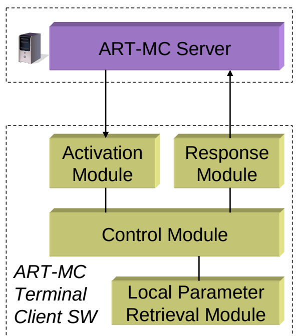


Fig. 3. ART-MC Terminal Client functional architecture

As already discussed, the ART-MC system requires the presence of appropriate software components at the terminal side. As depicted in Fig. 3, four modules compose the ART-MC Terminal Client: *(i)* The Activation Module, which waits for the ART-MC Server's querying messages and triggers the Control Module whenever such a message is received. *(ii)* The Control Module, which translates the incoming queries, so as to determine which local parameters are being requested. It also orchestrates the overall process. *(iii)* The Local Parameter Retrieval Module, which retrieves the requested data (for example, location, speed, etc.) through system calls to the native OS. *(iv)* The Response Module, which encapsulates the retrieved data in a standard format and delivers them to the ART-MC Server.

### *D. ART-MC Server Functional Architecture*

Fig. 4 depicts the functional architecture of the ART-MC Server, which comprises four modules: *(i)* The AS-Com Module, which receives requests from and transmits responses back to the Application Servers. *(ii)* The AMC-Com Module, which is responsible for issuing queries to anonymous mobile community (AMC) members and for collecting their responses. *(iii)* The Control Module, which analyzes the requests of the Application Servers, in order to select the appropriate query targets and form the appropriate query messages. It also orchestrates the overall process. *(iv)* The Local Database Management Module, which is delegated to retrieve information from the database that contains the list of registered users and their profiles.

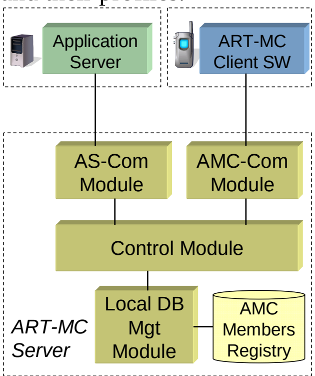

Fig. 4. ART-MC Server functional architecture

## IV. RESEARCH TOPICS

### *A. Anonymity and Privacy*

One of the central requirements of the ART-MC concept is the preservation of the end-user's anonymity and privacy. Pertaining to anonymity, the desired functionality is twofold:

- Firstly, the service requestor, as well as the Application Servers, should not be able to resolve the identities of the community members that are to be queried.
- Secondly, the queried community members should not be able to resolve the identity of the service requestor.

For this purpose, the ART-MC Server intervenes in the service delivery process. Hence, no direct communication between the Application Servers and the queried terminals is allowed. In addition, no direct communication between the queried terminals and the service requestor is permitted.

As opposed to the Application Servers, which may belong to any service/application provider, the ART-MC Server belongs to a trusted by the end-users party, such as the network operator. The ART-MC Server is responsible for impersonalizing the collected data:

- by replacing the MSISDN (Mobile Station International ISDN Number) of each queried terminal with an alias, or
- by completely removing the MSISDN.

Pertaining to privacy issues, the ART-MC software at the terminal side fulfills the following requirements: *(i)* it is allowed to communicate only with the ART-MC Server; *(ii)* it does not collect any sensitive data; *(iii)* it is installed only with the user's explicit consent; and *(iv)* it is signed by a trusted certificate authority.

### *B. Scalability*

The most crucial scalability parameter in the operation of an ART-MC service is the traffic load produced on the uplink by the responses of the users (queried terminals) that have enabled the Anonymous Mobile Community (AMC) functionality. These responses are produced and uploaded by the queried terminals almost concurrently. In the following, a representative feasibility and scalability study is provided, which reveals that current wireless access networks can adequately support the provision of ART-MC services. Two different cases of uploading AMC responses are examined: *(i)* using SMS via GSM, and *(ii)* through GPRS data sessions.

#### *1) SMS Responses in GSM Networks*

*Model parameters*:

- **N:** Number of users per cell
- **$p_{AMC}$:** Percentage of users that have enabled the AMC functionality
- **$N_{AMC}$:** Number of users per cell that have enabled the AMC functionality
- **$r_{AMC}$:** AMC response rate, i.e. number of responses per AMC user per hour
- **$m_{SMS/resp}$:** Number of SMSs per AMC response
- **$n_{SDCCH}$:** Number of available SDCCHs (Stand-alone Dedicated Control Channels) per cell
- **$T_{SMS}$:** Typical time that a single SDCCH is held by an individual SMS session

In real systems, a typical value for $T_{SMS}$ ranges from 4 sec to 5 sec [8]-[9]. Also, the total number of SDCCHs available in a cell is typically equal to twice the number of carriers, or one per three to four voice channels (the actual allocation of SDCCH channels may vary across implementations) [8]. For example, in an urban location where a total of four carriers are used, a total of eight SDCCHs are typically allocated.

*Performance metric*:

- **T:** Total delay for the transmission of all AMC responses corresponding to an individual query

*Scenario 1.1*:

- **N** = {30, 40, 50, 60, 70, 90, 100} users
- **$p_{AMC}$** = {10%, 20%, 30%, 40%}
- **$m_{SMS/resp}$** = 1 SMS
- **$n_{SDCCH}$** = 8 SDCCHs
- **$T_{SMS}$** = 4 sec

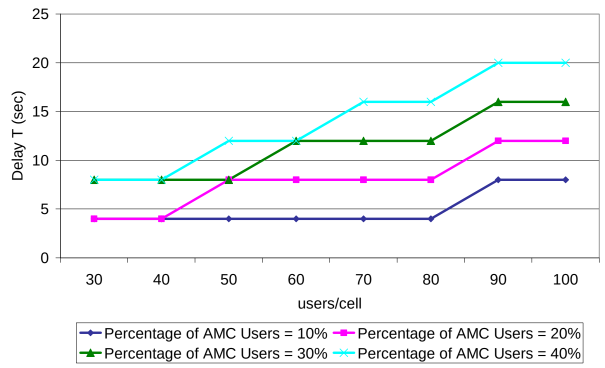


Fig. 5. Scenario 1.1 – Delay *T* vs. number of users/cell, for different values of the percentage of AMC users

Fig. 5 is a plot of the delay *T* vs. the number of users/cell, for different values of the percentage of users that have enabled the AMC functionality. As may be observed, the delay *T* varies from 4 sec to 20 sec. By assuming that a logical threshold for qualifying an AMC service as real-time or not is *30 sec*, it can be deduced that the system remains feasible and scalable even in cases of large target subgroups (e.g., 40%). Taking as reference the average case of $p_{AMC}$=20% (which corresponds to a significantly high market penetration for a newly introduced service) and *N*=70, the delay *T* is restricted to reasonable limits (8 sec).

*Scenario 1.2*:

- **N** = {30, 40, 50, 60, 70, 80, 90, 100} users
- $\mathbf{p_{AMC}}$ = 20%
- $\mathbf{N_{AMC}}$ = {6, 8, 10, 12, 14, 16, 18, 20} AMC users
- $\mathbf{m_{SMS/resp}}$ = 1 SMS
- $\mathbf{n_{SDCCH}}$ = {4, 6, 8} SDCCHs
- $\mathbf{T_{SMS}}$ = 4 sec

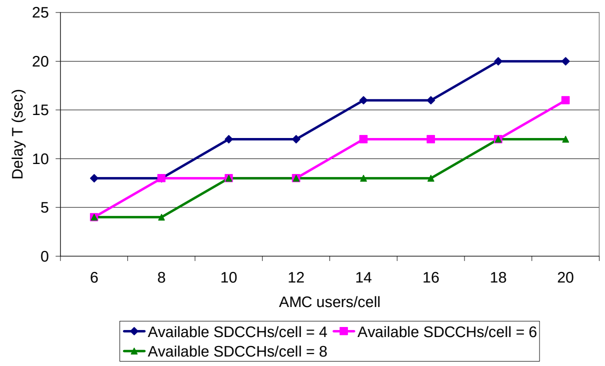


Fig. 6. Scenario 1.2 – Delay *T* vs. number of AMC users/cell, for different values of the number of available SDCCHs/cell

Fig. 6 is a plot of the delay *T* vs. the number of AMC users/cell, for different values of the number of available SDCCHs per cell. As may be observed, the delay *T* varies from 4 sec to 20 sec. By assuming that a logical threshold for qualifying an AMC service as real-time or not is *30 sec*, it can be deduced that the system remains feasible and scalable even in cases of low availability of SDCCHs/cell (e.g., 4). Taking as reference the average case of $n_{SDCCH}$=6 (which corresponds to a slightly underestimated value for urban areas) and $N_{AMC}$=14, the delay *T* is restricted to reasonable limits (12 sec).

*2) GPRS Data Session Responses*

*Model parameters*:

- **N:** Number of users per cell
- $\mathbf{p_{AMC}}$**:** Percentage of users that have enabled the AMC functionality
- $\mathbf{N_{AMC}}$**:** Number of users per cell that have enabled the AMC functionality
- $\mathbf{r_{AMC}}$**:** AMC response rate, i.e. number of responses per AMC user per hour
- $\mathbf{L_{resp}}$**:** Length (in bytes) of an AMC data message response, including payload and protocol overheads
- $\mathbf{n_{PDCH}}$**:** Number of PDCHs (Packet Data channels) per cell that can be used by AMC users
- $\mathbf{R_{PDCH}}$**:** Baseband speed (bit rate) of a PDCH, assuming coding scheme CS-2
- $\mathbf{a_{PDCH}}$**:** Availability of the PDCH

*Performance metrics*:

- **T:** Total delay for the transmission of all AMC responses corresponding to an individual query
- $\mathbf{u_{AMC}}$**:** Utilization factor of PDCHs due to AMC traffic

The $u_{AMC}$ metric represents the generated AMC traffic as a percentage of the maximum traffic that can be transferred by the cell's PDCHs. In the following scenarios, we only consider the worst cases that can be met concerning the AMC feasibility and scalability. In particular, it will be assumed that only a percentage (i.e., $a_{PDCH}$ < 100%) of a single (i.e., $n_{PDCH}$ = 1) PDCH is available for supporting the AMC functionality. This is evidently a greatly pessimistic perspective, which is employed in order to prove the system's feasibility even for the worst possible cases.

*Scenario 2.1*:

- **N** = {30, 40, 50, 60, 70, 80, 90, 100} users
- $\mathbf{p_{AMC}}$ = 20%
- $\mathbf{N_{AMC}}$ = {6, 8, 10, 12, 14, 16, 18, 20} AMC users
- $\mathbf{L_{resp}}$ = 300 bytes
- $\mathbf{n_{PDCH}}$ = 1
- $\mathbf{R_{PDCH}}$ = 13.4 Kbps
- $\mathbf{a_{PDCH}}$ = {100%, 75%, 50%, 25%}

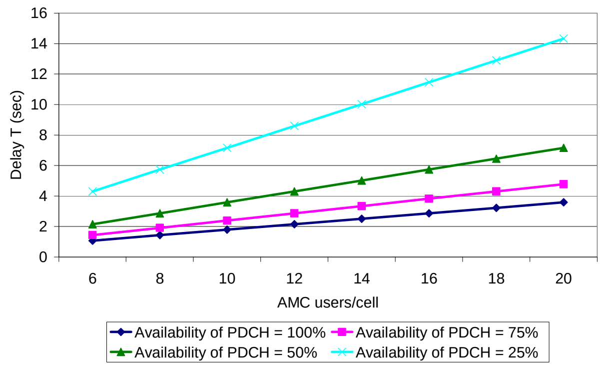


Fig. 7. Scenario 2.1 – Delay *T* vs. number of AMC users/cell, for different values of the availability of the PDCH in use

Fig. 7 is a plot of the delay *T* vs. the number of AMC users/cell, for different values of the availability of the PDCH in use. As may be observed, the delay *T* varies from approximately 1.1 sec (100% availability, 6 AMC users) up to 14.3 sec (25% availability, 20 AMC users). By assuming that a logical threshold for qualifying an AMC service as real-time or not is *30 sec*, it can be deduced that the system remains feasible and scalable even in cases of low availability of the PDCH in use (e.g., 25%).

*Scenario 2.2*:

- **N** = {30, 40, 50, 60, 70, 80, 90, 100} users
- $\mathbf{p_{AMC}}$ = 20%
- $\mathbf{N_{AMC}}$ = {6, 8, 10, 12, 14, 16, 18, 20} AMC users
- $\mathbf{r_{AMC}}$ = {2, 4, 6, 8} responses/AMC user/hour
- $\mathbf{L_{resp}}$ = 300 bytes
- $\mathbf{n_{PDCH}}$ = 1
- $\mathbf{R_{PDCH}}$ = 13.4 Kbps
- $\mathbf{a_{PDCH}}$ = 50%

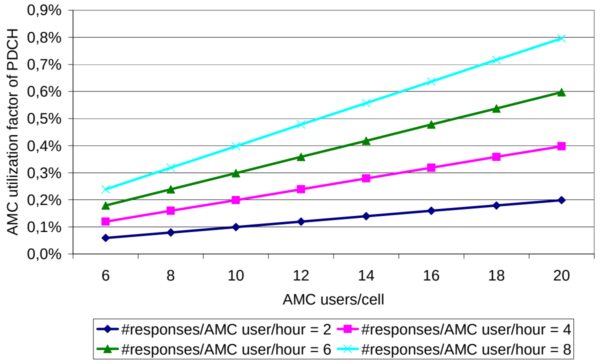


Fig. 8. Scenario 2.2 – AMC utilization factor of the PDCH in use vs. number of AMC users/cell, for different values of the AMC response rate

Fig. 8 is a plot of the AMC utilization factor of the PDCH in use vs. the number of AMC users/cell, for different values of the AMC response rate. As may be observed, the utilization factor $u_{AMC}$ varies from 0.06% (2 responses/AMC user/hour, 6 AMC users) up to 0.79% (8 responses/AMC user/hour, 20 AMC users). From this it can be deduced that the provision of AMC services through GPRS networks does not cause any considerable system performance degradation. The same conclusion can be reached for UMTS and WiFi networks, since the latter have higher bandwidth and traffic-handling capabilities than typical GSM/GPRS networks.

## V. Example Applications

The ART-MC concept can be exploited in the context of the following example applications:

- *Vehicular Traffic Conditions*: This service deals with the provision of real-time information concerning road-traffic conditions. The service requestor indicates the area/ road/ highway in question. The information that must be collected includes the position and velocity of the community members.
- *Clubbing/Restaurants Information*: This application is concerned with the provision of information regarding the popularity of clubs (or restaurants). Indicative questions that a service requestor may ask are: "What is the popularity of club C right now?", or "What is the popularity of club C over the past week?". Thus, in this use case scenario, the anonymous community is a community of "clubbers". The information collected includes the positions of the community members, the time they spend in these positions, and optionally their explicit opinions or views about the clubs they visit.
- *File Sharing*: A file-sharing application may also be deployed using the ART-MC mechanism. This application will enable users to share content that is stored in their mobile terminals. The information that must be collected is the index of each user's shared files.
- *Environmental Applications*: Environmental applications may exist as well, e.g. informing end-users about the temperature levels in the areas of interest. The collected information includes the monitored environmental parameters, such as the temperature, which can be retrieved through the temperature sensor of the terminal's battery or through an integrated digital sensor.

In general, a variety of heterogeneous applications may be supported by the proposed architecture; for example, mobile multiplayer gaming applications, chatting and socializing applications, emergency services, etc. may be provided as well. The ability to deliver diverse services and applications via the same framework is one of the main advantages of the proposed concept.

## VI. Conclusions

This paper presented the innovative concept of Anonymous Real-Time Mobile Community (ART-MC) services. The proposed architecture, targeted for the deployment of ART-MC services, was described in detail. The relevant anonymity and privacy issues were investigated and a thorough scalability study was presented. Finally, example applications were identified and outlined.

Further research activities will focus on: *(i)* implementation and trials of further applications based on the concept, and *(ii)* planning and validation of potential business schemes for the commercial success of ART-MC services.

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