ELECTRONICS AND ELECTRICAL ENGINEERING
ISSN 1392 – 1215 2009. No. 7(95)
ELEKTRONIKA IR ELEKTROTECHNIKA

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Air Data Systems – Integrated Multi System Wireless Networks

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Introduction

Most current and emerging consumer devices are being equipped with multiple network interfaces, thus enabling connectivity via multiple wide-area (e.g., UMTS, CDMA2000), local-area (e.g., IEEE 802.11), or personal-area (e.g., Bluetooth) wireless access technologies. In the emerging *integrated wireless network infrastructure* [4], an intelligent mobile node (MN) will thus be capable of simultaneously connecting to, or seamlessly switching between, multiple wireless access technologies, potentially operated by distinct service providers. In this paper, we shall investigate the challenges and opportunities available for the two fundamental operations—*location update* and *paging*—associated with the location management problem in such an integrated environment.

Multimedia Reference Model

For complex systems, such as networked multimedia systems, an overall conceptual framework is strongly needed. The knowledge and the interests of all concerned parties are too different to meet their needs with a single view to the system. Different views have to be offered to the end user, the application designer, provider, and the operator as well as to the network operator and the component manufacturer. Fig. 1 shows the Multimedia Reference Model that we developed from the INCM (Intelligent Network Conceptual Model), based on our experiences with the realization of IN concepts in form of the service creation environment PHIDES and of the Open Switching platform.

The Application Plane describes the end user's view to the offered applications. Examples for such applications are telediagnosis, teleshopping, interactive TV shows, video on demand, or multi-user. We replaced the INCM's term 'Service Plane' by 'Application Plane' because 'service' is a generic notion (e.g. each of the seven layers of the OSI reference model offers its 'services' to the next higher layer).

The Global Feature Plane defines the application building blocks (ABB) of the networked, interactive, multi-user, multimedia applications described on the Application Plane. Those. application building blocks are combined to construct the service logic of an application. In Fig. 1 the features charging and billing, service access, user access, and communication control are shown exemplary. These application-independent features take care of the commonalities among the different applications. Communication control refers to the logical ability to bring two or more parties together and to allow them to participate in a multimedia session.

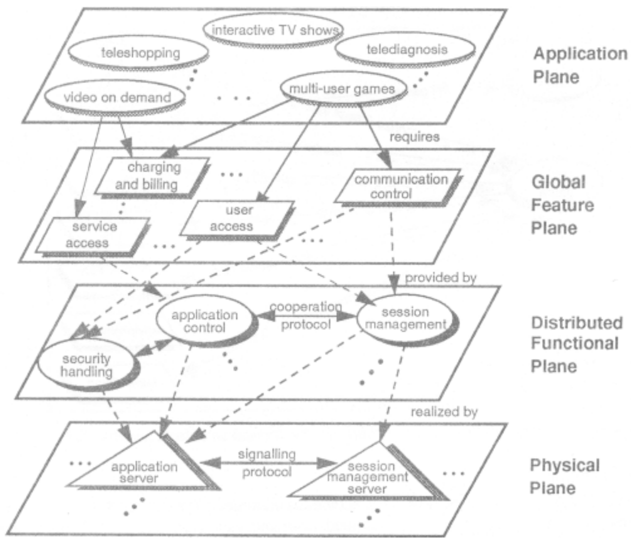

Fig. 1. Data service reference model

The Distributed Functional Plane describes the functional entities and cooperation protocols between them, defining a functional architecture. Application control, security handling and session management are examples of important system functions to be provided by a distributed multimedia system. Other functions are e.g. network management, subscription and subscriber management and information access function. The functional architecture is defined such that it can provide the functionality needed for the application building blocks at the global feature plane.

The Physical Plane describes the possible distribution scenarios that can reach from centralized realization of single-vendor solutions to the maximum distribution where every functional entity of the Distributed Functional Plane is realized as a physical component by an independent organisation.

Intuitively, significantly better location prediction, with lower signaling overhead, can be achieved by utilizing the *strong correlation* present in the location data across different networks for a single MN. In practice, an integrated access infrastructure is likely to be only loosely coupled, consisting of several independent cellular access networks, called *sub-networks*, managed by distinct service providers. Seamless access across such different provider sub-networks would typically be supported through unified roaming and AAA (authentication, authorization and accounting) mechanisms, such that each provider exerts control on the specifics of the location management scheme within its own sub-network. To be effective, the location tracking strategy:

- cannot assume the use of either a common location coordinate system by all sub-networks or a universal topology translation database to translate location coordinates across sub-networks;
- may not rely on specific network or link-layer features that could be absent in one or more sub-networks;
- cannot assume any particular cellular topology or layout. Unlike prior work (e.g., [7]), the scheme should not be restricted to inter-system handoffs at only sub-network boundaries, but allow for arbitrary overlap (including total containment) between cells of different sub-networks.

Based on these basic location update and paging algorithms, we shall present and comparatively evaluate three alternative location management strategies, which differ in the degree of inter-sub-network coordination needed.

- In the *centralized* scheme, the entire location update and movement history for a particular MN is stored at a central coordinating server, which determines the paging sequence across all sub-networks.
- In the *distributed* scheme, each individual sub-network possesses complete information about the mobile's combined movement-and-calling sequence in all sub-networks. By eliminating the central coordinator, it allows the location management scheme to be completely distributed, at the expense of higher update cost on the MN.
- In the *quasi-distributed* scheme, a central coordinator stores only aggregate statistics about the MN's location uncertainty in each sub-network, rather than the complete movement history of the MN. An MN issues location updates selectively to individual sub-networks, thereby reducing its location update cost at the expense of higher paging overhead.

Global Feature Plane

The Global Feature Plane offers a simplified view to the networked multimedia system, suitable for an application designer. Within the service logic many aspects of multimedia communication are hidden by abstractions which we call Application Building Block (ABB). These Application Building Blocks are software objects which offer the needed logical view via their operations. They are used by the application objects that are written by the application designer. We offer seven Application Building Blocks on the Global Feature Plane of our Multimedia Reference Model. These seven ABBs are shown on the right side of Fig. 2, which outlines their use in a multi-user game application. This figure only indicates the 'use' relation between an application instance, i.e. multi-user game, and the ABBs. It does not give a complete specification of a service logic and of the timely order of the invocations.

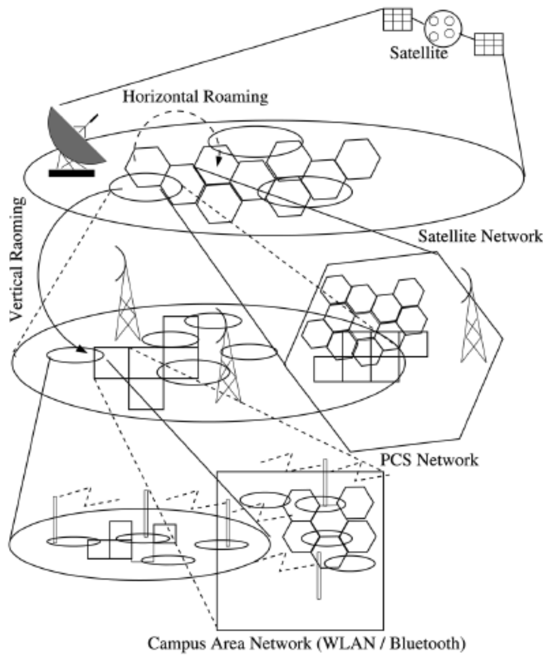

Fig. 2. A multi-system heterogeneous wireless network

In the following, we describe as an example the communication control object class which is a very important one. The operations forming its public interface are:

- *changeTopology*, which adds respectively removes a new construct to respectively from a session, i.e. a medium, a relator, a synchronization relation, or even creates a complete session. The relator is an enhanced version of the Touring Machine.
- *changePrivilege*, which supports a wide variety of communications privileges of the participants in an application. Besides the classic privileges "read" (i.e. also 'listen' or 'watch') and write (Le. also 'speak' or 'show'), sophisticated ones are provided like 'read but not copy'.
- *changeQuality*, is used for the modification of quality of service characteristics (such as bandwidth, delay, jitter, or synchronization). Additionally, the required confidence of communicated data is arranged with this operation.
- *setDP* makes the explicit event handling for the multi-user, multimedia session possible. Detection points (DPs) can be activated for a collection of session events. If the corresponding event occurs, the DP fires and the communication control object informs the service logic. The basis of our DP mechanism are the ITU- T recommendations for IN.

Related work on location management

Existing PCS networks typically cluster groups of cells into *registration areas* (RA), such that the location uncertainty of an MN is confined to its last reported RA. In this approach, an MN performs proactive location updates only when it changes its current RA, and not on every cell-change. In general, location update strategies can be classified into three categories:

- distance-based,
- movement-based,
- time-based;

System description and location uncertainty

The topological layout of an integrated network in Fig. 2 shows that the coverage area of an individual sub-network can be discontinuous (e.g., a set of disconnected islands of 802.11-based hot-spots). Accordingly, the set of sub-networks that can be accessed concurrently by an MN is not constant, but a function of its current location. Mathematically, let the integrated network consist of N sub-networks or access technologies $\{S_1, S_2, ..., S_N\}$, where each sub-network is a collection of (either partitioned or overlapping) cells. Let C_i^j represent the *j*-th cell in the *i*-th sub-network S_i, and let $|S_i|$ represent the cardinality of (number of cells in) S_i. The location of an MN at any instant can then be represented as a vector-valued random variable $\overline{X}$ of dimension *N*, where the *i*-th element of the vector corresponds to the current cell of sub-network S_i. For example, if $\overline{X}(2) = 4$, the MN is currently located in the fourth cell of sub-network S_2. As some of the sub-networks may be hotspot-based (e.g., 802.11), thus providing isolated islands of coverage, an MN may frequently roam outside the coverage of a specific individual sub-network. For notational convenience, let each sub-network have an additional cell ϕ to capture this disconnected state. Accordingly, if the MN is currently out of coverage of S_i, its location vector includes the cell C_i^{ϕ}. To model the multi-system environment, where different sub-networks may have different paging and location update costs per transmitted message, let PG_i represent the cost of transmitting a single paging message in a single cell, and let LU_i be the cost of transmitting a single location update message in a cell of the *i*-th sub-network S_i.

Similar to the LeZi-Update scheme [5], our location update strategy views the MN's movement pattern as a sequence of symbols and issues location updates, not at each movement of the MN, but only on an appropriately determined (entropy - coded) subset of this movement sequence. While the LeZi-Update scheme can be applied to movement - based strategies, time - based strategies, and distance-based strategies, without loss of generality, we consider a movement-based location update strategy where a new symbol is generated only when the MN changes a cell in any one of the sub-networks.

The probability of finding the MN in a specific location can be modeled by the joint probability distribution

$$\Pr\left(\overline{X} = [x_1, x_2, x_3, ..., x_{N-1}, x_N]\right) \qquad (1)$$

$$\Pr ob\left(MN \textit{ is located in } C_1^{x_1} \cap C_2^{x_2} \cap C_3^{x_3} \cap ... \cap C_N^{x_N}\right), \qquad (2)$$

where x_i represents the MN's cellular coordinate in S_i. Note that one or more of these elements may have the value ϕ. The movement of an MN may then be viewed as a stochastic, vector valued process $\chi = \{X^n\}$ which would then be associated with an entropy bound $H(\chi)$, formally defined as

$$H(\chi) = \lim_{n\to\infty} H\left(\overline{X_n} / \overline{X_0}, \overline{X_1}, ..., \overline{X_{n-+}}\right), \qquad (3)$$

where $H(\chi) = -\sum_{\overline{x}\in\chi} \Pr(\overline{x}) \lg[\Pr(\overline{x})]$.

Since the vector-valued entropy in (3) does not account for the fact that different update/paging messages (corresponding to different sub-systems) have different costs, we propose the concept of weighted entropy or the minimum weighted cost per movement. Note that, for the movement – based location update, the random vector $\overline{X_n}$ differs from the random vector $\overline{X_{n-1}}$ only in one element, i.e., an MN changes its cellular coordinate in only one sub-network at a time. Ideally, the MN informs its location update to a centralized location tracking system using the sub-system S_i where it has changed cells, thereby incurring an update cost of LU_i. The cost of conveying an information change in the *i*-th element of the random vector $\overline{X}$ is thus weighed in proportion to the associated update cost, LU_i. Accordingly, the weighted entropy is given by

$$H_w(\chi) = -\lim_{n\to\infty} \sum_{i=1}^{N} LU_i * \sum_{j=1}^{|S_i|} h(n, j) * \log_2 h(n, j) \qquad (4)$$

with

$$h(n, j) = \Pr\left[\overline{X_n} = \left(..., C_i^j, ...\right) / \overline{X_{n-1}}, ... \overline{X_0}\right], \qquad (5)$$

where the … imply that the corresponding random variables can take any possible value within its range. This weighted entropy measure is not of direct relevance to our update strategies which employ multidimensional Lempel-Ziv (LZ) compression without any apriori knowledge of the underlying movement statistics of the MN. The weighted entropy value $H_w(\chi)$ merely captures the true theoretical lower bound on the signaling cost that any feasible location update strategy must incur.

Need for Session State Information

While (5) captures the weighted cost in performing location updates, it does not exploit the correlation between the movement and session arrival patterns, which can be important for location tracking in a multi-system environment. Note that the session state activity is needed only if we assume that a sub-network can issue only aggregate paging requests to another (target) sub-network, and not directly request paging in an individual cell. In a single-system environment, the MN is paged only when it is currently idle in that system. On the other hand, in a multi-system environment, paging can also be performed in one sub-network by employing signaling in another sub-network to trigger a location update in S_i.

To capture the MN's session activity state, we first define another vector-valued random variable $\overline{R}$ such that its binary valued *i*-th element corresponding to the MN's activity state in S_i is given as

$$\overline{R_i} = \begin{cases} 0 & \text{if } MN \text{ is idle in } S_i, \\ 1 & \text{if } MN \text{ is active in } S_i. \end{cases} \tag{6}$$

Now, to exploit the correlation between $\overline{X}$ and $\overline{R}$, we define a $2N$-valued random vector $\overline{K}$, consisting of alternating elements of $\overline{X}$ and $\overline{R}$.

Conclusion

We have proposed an information-theoretic location management strategy for emerging multi-system wireless networks.

The framework is powerful as it exploits the correlation in the user's location (and in some cases, its calling pattern) across individual sub-networks, without requiring a public global database. We have developed the concept *of weighted entropy,* as the most fair measure of location uncertainty of the mobile node (MN) in heterogeneous sub-networks.

References

1. **Akyildiz I. F., Wang W.** A dynamic location management scheme for next-generation multitier PCS systems // IEEE Trans. Wireless Commun. – January 2002. – Vol. 1, No. 1. – P. 178–189.
2. **Bar-Noy A., Kessler I.** Tracking mobile users in wireless communication networks // IEEE Trans. Inf. Theory. – November 1993. – Vol. 39, No. 6. – P. 1877–1886.
3. **Bar-Noy A., Kessler I., Sidi M**. Mobile users: To update or not to update // Wireless Netw. – July 1995. – Vol. 1, No. 2. – P. 175–185.
4. **Berezdivin R., Breinig R., Topp P.** Next-generation wireless communications concepts and technologies // IEEE Commun. Mag. – March 2002. – Vol. 40, No. 3. – P. 108–116.
5. **Bhattacharya A., Das S. K**. LeZi-Update: An information-theoretic approach for personal mobility tracking in PCS networks // Wireless Netw. – March 2002. – Vol. 8, No. 2. – P. 121–137 (Also Proc. ACM MobiCom. – 1999).
6. **ITU-T, Study Group 8.** T.120: Transmission Protocols for Multimedia Data. – 20 March 1995.
7. **Volner R., Boreš P**. ATN Networking – Policy based Management for Enterprise and Carrier // Poster Abstract of the 27th International Conference on Information Technology Interfaces ITI 2005. – Cavtat/Dubrovnik, Croatia. – June 2005. – P. 37–38.
8. **Volner R**. Aviation Data Networks – New Avenues for Flight Safety, Security Issues and Network Architecture // Poster Abstract of the 27th International Conference on Information Technology Interfaces ITI 2005. – Cavtat/Dubrovnik, Croatia. – June 2005. – P. 35–36.

Received 2009 03 17

R. Volner, V. Smrž. Air Data Systems – Integrated Multi System Wireless Networks // Electronics and Electrical Engineering. – Kaunas: Technologija, 2009. – No. 7(95). – P. 41–44.

Aircraft data networks are fast becoming more of a necessity due to their support for user mobility. Many aircraft manufacturers are planning to deploy data networks within their airplanes and provide internet connectivity to their passengers. While a data network within the aircraft and passenger access to it causes some security concerns, it open up some safety enhancement opportunities. With internet connectivity within the airplane, the activity within the airplane can be monitored in real-time from the ground station. Also, using the high bandwidth satellite links, the flight critical data could be downloaded to a server in the ground station in real-time flight or periodically, thereby enabling real-time flight status monitoring. In a multi-system environment where a mobile node can utilize multiple interfaces and simultaneously connect to multiple providers, new opportunities exist for efficient location management strategies spanning heterogeneous cellular wireless networks. An integrated framework is developed for location management in such a multi-system, fourth generation (4G) wireless networks. This information-theoretic framework allows each individual sub-system to operate fairly independently, and does not require the knowledge of individual sub-network topologies. An efficient location management in such a loosely coupled network is designed by having a mobile node view its movement as a vector-valued sequence, and then transmit this sequence in an entropy coded form to the network. Ill. 2, bibl. 8 (in English; summaries in English, Russian and Lithuanian).

Р. Волнер, В. Смрж. Системы аэропередачи данных четвертого поколения // Электроника и электротехника. – Каунас: Технология, 2009. – № 7(95). – С. 41–44.

Описываются системы передачи данных в самолетах, когда для удобства пассажиров предлагаются услуги интернета. В данном случае связь с оператором интернета позволяет и пассажиру установить место нахождения. Предлагается структура системы связи четвертого поколения. Ил. 2, библ. 8 (на английском языке; рефераты на английском, русском и литовском яз.).

R. Volner, V. Smrž. Oru perduodamų duomenų sistemos – integruoti daugelio sistemų belaidžiai tinklai // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2009. – Nr. 7(95). – P. 41–44.

Orlaivių duomenų tinklai greitai tampa būtinybe, nes jais gali naudotis mobilūs vartotojai. Daugelis gamintojų savo orlaiviuose planuoja įrengti duomenų tinklus ir keleiviams teikti interneto paslaugas. Nors tokie tinklai kelia tam tikrų saugumo problemų, jie taip pat suteikia tam tikrų galimybių padidinti saugumą. Orlaivyje įdiegus interneto ryšį, jame vykstančius įvykius ir techninius parametrus būtų galima stebėti realiu laiku iš antžeminės stoties. Svarbi skrydžio informacija būtų parsiunčiama į antžeminės stoties serverį realiu laiku arba periodiškai, panaudojant didelio pralaidumo palydovinius kanalus. Daugelio sistemų aplinkoje mobilusis tinklo mazgas gali sudaryti ryšį su keliais ryšio tiekėjais ir taip suteikti galimybes sukurti efektyvias mazgo buvimo vietos nustatymo strategijas, apimančias heterogeninius belaidžius korinius tinklus. Sukurta šią funkciją įgyvendinančios ketvirtosios kartos belaidžiams tinklams skirtos sistemos struktūra. Ji leidžia pavienėms posistemėms veikti palyginti nepriklausomai ir nereikalauja informacijos apie atskirų potinklių topologijas. Il. 2, bibl. 8 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).