NEXUS – POSITIONING AND COMMUNICATION ENVIRONMENT FOR SPATIALLY AWARE APPLICATIONS

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ABSTRACT

The research project "NEXUS" aims at the development of a generic platform that supports location aware applications for mobile users. It is currently being carried out within a so-called research group supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) in cooperation between the Institute for Photogrammetry, the Institute of Parallel and Distributed High-Performance Systems and the Institute of Communication Networks and Computer Engineering of the University of Stuttgart.
A major task of the platform is the providing of a positioning service in outdoor and indoor locations. Additionally a communication environment must be defined to facilitate an exchange between the external information sources and virtual objects. The spatially aware applications are available for the user on small handheld devices like PDAs (**P**ersonal **D**igital **A**ssistants). These computers are equipped with sensors for positioning and mobile communication. In this way, the application is aware of the users' position within the spatial models. Users are "location aware" and can receive spatial data from distributed servers. In order to support them on their way, several functionalities have to be provided: users have to be able to navigate and to perform queries on their environment, thus an interface to GIS has to be implemented.

KURZFASSUNG

Innerhalb des Forschungsprojekt "NEXUS" wird eine generische Plattform entwickelt, die ortsbewusste Anwendungen mit mobilen Nutzern unterstützt. Das Projekt wird im Rahmen einer DFG (Deutsche Forschungsgemeinschaft) geförderten Forschergruppe bearbeitet. Neben dem Institut für Photogrammetrie sind an der Forschergruppe drei weitere Projektpartner beteiligt. Zum einen das Institut für parallele und verteilte Höchstleistungsrechner, mit den Abteilungen verteilte Systeme und Anwendersysteme, sowie das Institut für Nachrichtenvermittlung und Datenverarbeitung, der Universität Stuttgart.
Das Ziel der NEXUS Plattform ist u.a. die Entwicklung eines Positionierungsservices für Außen- und Innenräume. Daneben muss eine Kommunikationsumgebung definiert werden, die einen Informationsaustausch zwischen externen Informationsquellen und virtuellen Objekten ermöglicht, die als Vermittler dienen. Die „ortsbewussten" Anwendungen lassen sich dann auf einem kleinen „Handheld" Computer, wie z.B. einem PDA (**P**ersonal **D**igital **A**ssistent) betreiben. Diese Computer sind zusätzlich mit Positionierungssensoren und Geräten zur mobilen Kommunikation ausgestattet. Aufgrund dieser Tatsache ist die Applikation jederzeit über die Position eines Benutzers im räumlichen Modell informiert. Die mobilen Nutzer sind damit ortsbewusst und haben gezielten Zugriff auf die räumlichen Daten, die auf verschiedenen Servern verteilt sind. Um eine zusätzlich Benutzerführung zu gewährleisten, müssen verschiedene Funktionalitäten bereitgestellt werden: Den Nutzern soll es möglich sein zu navigieren und räumliche Anfragen bezüglich ihrer gegenwärtigen Umgebung zu stellen, wozu ein Interface zu GIS bereitgestellt werden muss.

1 MOTIVATION

1.1 General Aspects of NEXUS

The traditional task for persons navigating in outdoor areas is solved by several different orientation tasks: The person must look at 2D-map, additionally compass and GPS measurements are used to support the orientation process, this information has to be matched to the surrounding environment mentally. Also the amount of information a person is confronted with is increasing more and more. In fact this is a real problem because often one is occupied with different things and the navigation itself is additional stress. A navigation tool for pedestrians would support a user in a suitable way. But not only navigation is a problem. The amount of information (e.g. WWW) a person is confronted with is increasing more and more. The modern environment is minted by surrounding information systems and mobile communication. Although single applications exist to take access to information sources they are not location aware (see Fig. 1). In order to give support with specific information, the spatial component of the information can be a decisive factor. Location aware applications that "know" the position of their users are considering this fact and prepare information according to a user's location. For this reason, they refer to spatial models that allow the assignment of information to a certain position. The NEXUS platform provides the management of the positioning components and the spatial models representing physical world. They are the basis for the NEXUS infrastructure and not only serve for particular, but for location aware applications in general.

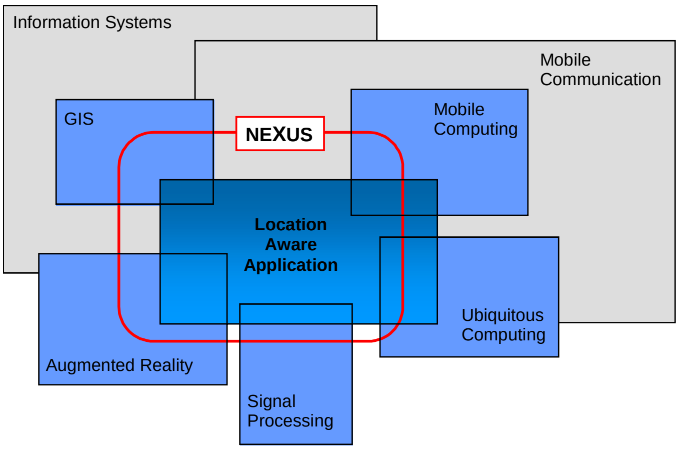


Figure 1: NEXUS and the relation to single applications

1.2 An Application Scenario

To get an impression of the functionalities of the NEXUS platform, this part will illustrate the main ideas by means of an application scenario: it is planned to establish an information system based on NEXUS for the city of Stuttgart, Germany.

One could imagine a user arriving at Stuttgart's central station to attend a conference in town. To find the way in the unknown environment, he utilizes a NEXUS station, a small mobile computer (PDA). The PDA knows the current position and is able to get into contact with the NEXUS platform by wireless communication. Using his NEXUS-station, the user visits the web sites of the tourist information. These sites provide different services like the possibility to search for trains and to cash up the fare for public transport automatically via NEXUS. After having specified his destination, NEXUS is showing the line number and the departure time of the train that leads him to the location where the conference takes place. After the meeting he is going to the city for a stroll. As he sees a historical building, he just points at it with the telepointing device, integrated in the NEXUS station. Directly, all historical and architectural facts about the object are transmitted to his PDA. While he is proceeding, the NEXUS station gives an audio signal and calls the attention of the user to an incoming message. A department store informs all the people passing by about special offers. The NEXUS-station is able to filter messages dependent on the user profile specified for each user individually. This profile also provides information concerning the acceptance to receive external information. The user is interested in one of the special offers and enters the building. Automatically the NEXUS station switches to the department store information system, that leads him to the product he is interested in. A virtual information tower, which is placed near the product, informs the user about special product information, e.g. technical details, WWW address of the manufacturer, etc. Furthermore, the user is able to fix a virtual post it to a product, in order to inform other users, e.g. he can tell them something about the product.

2 THE NEXUS PLATFORM

2.1 Architecture of the System

The architecture of the NEXUS infrastructure consists of different components working together; in order to realize the aspired demands. Figure 2 represents the main components of the NEXUS platform. The user interface serves as transmitter and allows the appropriate use of services for the different applications. Therefore a well-defined interface is provided. The interior of a NEXUS platform is split into three main elements: communication, distributed data management and the sensor systems. To provide these capabilities, several requirements have to be fulfilled. The data safety and the confidentiality of the personal data must be ensured. Otherwise, an acceptance of the user could not be expected. Also an adequate response time is important, which only is achieved by a scalable infrastructure. Additionally breakdown prevention should be implemented and parameter changes have to be handled appropriately.

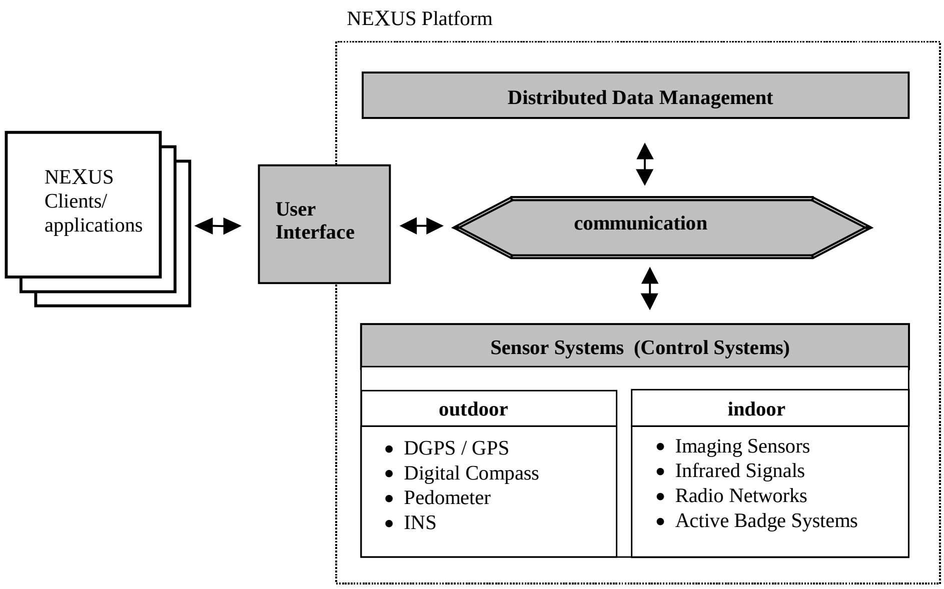


Figure 2: Architecture of the NEXUS Platform

2.2 User Interface

For interaction between the NEXUS clients (applications) and the NEXUS platform a user interface is necessary, running on the mobile device carried by the user. It contains basic functionality required for interaction with the NEXUS platform and for display and navigation through the model. It also provides support to adapt devices with different levels of computing power, amounts of memory, levels of network connection or different displays (see Fig. 3). A PDA e.g. will require a completely different user interface than a wearable computer. As NEXUS also aims the support of special applications within the NEXUS world, a GUI (**G**raphical **U**ser **I**nterface) will be the established. Here it is possible to create special GUI's for each local world to give the best support to the users, because the interface should allow easy communication between client and platform.

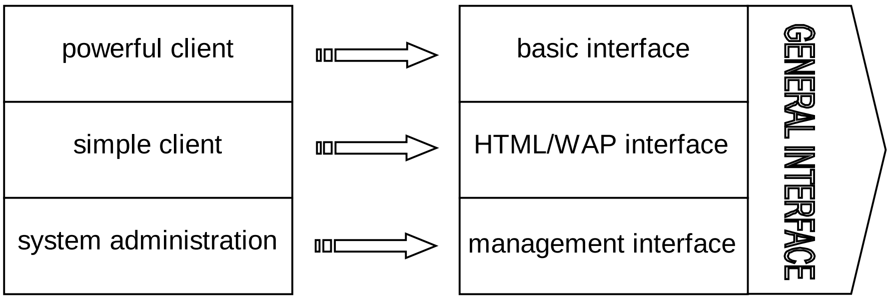


Figure 3: Interfaces for data access

3 POSITIONING SERVICE AND LOCATION AWARENESS

3.1 General

The aim is the development of a platform supporting spatial aware applications with mobile users. Hence, a user should be able to receive any relevant and required information at any time and any place. Real-time positioning is a prerequisite for spatial aware applications. An application is spatial aware when the positions of the mobile users and the objects in the real world are known. To provide the users awareness, real time GPS supplemented with additional sensors is used.

Locations where NEXUS applications are running could be subdivided in the outdoor and indoor area. Considering these two the use of only one sensor for positioning in both environments will be difficult. Therefore a multi-sensor positioning tool is required. Research results have shown, that the combination of tools based on different principles is necessary. Therefore, absolute sensors, relative sensors and also imaging sensors can be chosen. The use of imaging sensors does not provide direct position information. To extract location information from them, it is necessary to use image interpretation methods.

Summarizing the requirements, a user will be equipped with a multi sensor real-time tool, acting as a prerequisite for spatial aware applications. The real time (positioning) device will provide position information through an interface, where different kinds of sensors are used for the location determination.

3.2 Indoor Positioning

At this point the two areas where position information is required – indoor and outdoor – are considered in more detail. As already mentioned the sensors for positioning in these two regions are completely different, because outdoor sensors in general fail in indoor.

To provide the permanent location of a user, different strategies are considered. The positioning sensors for the outdoor and indoor region are completely different, e.g. outdoor sensors fail in indoor. Considering the indoor area, there is the possibility to use “Active Badge” systems, still video cameras or the “Bluetooth” technology for positioning. To give an overview, each of them will be described in detail.

3.2.1 The Active Badge System. The “Active Badge” (AB) system represents one possible indoor positioning tool. At Olivetti Research Ltd. a system was developed, which allows locating a person – equipped with a badge – within buildings (Want et. al. 1991). The working principle is like that of a transponder system. To realize such, each person wears a badge with a unique ID. If a person is moving through the building, the AB system is able to detect the position. The principle of this system is very simple but the realization causes some problems, particularly if the AB system should be provided for a city area. Any user must wear a special badge to utilize this indoor positioning service. In case of NEXUS it is doubtful if this system can act as an indoor positioning system, because costs will increase and the acceptance of the users probably will not be very high. Only for very few indoor areas it seems reasonable to use this system, e.g. fairs.

3.2.2 Still Video Cameras. A more suitable way for the indoor positioning is the use of still video cameras along with image interpretation. Objects, extracted from the images are used for location determination. In combination with spatial resection the position and orientation of the camera is determined indirectly. Due to the fact, that a user is “wearing” the camera, the position of the user approximately agrees with the camera position.

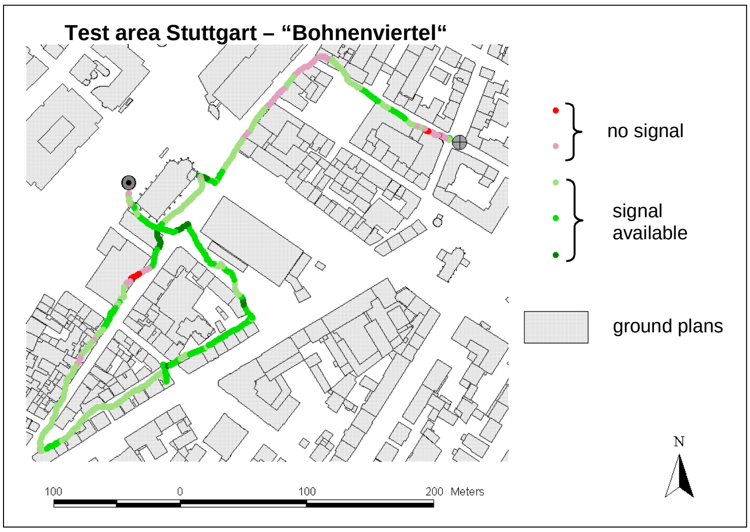
The process of object recognition is subdivided into data collection, pre-processing, segmentation, modelling (shaping) and matching. In a segmentation process points, lines and areas are identified for the matching. A representation of each object is contained in the model, by using its features. A correlation process filters the correspondence between the features of the scene and those of the object model. Within this process of identification and location, the position of the capturing device is obtained.
For the first implementation coded targets or signals (representing the objects) are used for the identification and location process (Ahn & Schultes 1997). In a next step, features from real objects serve as "tie points" for the positioning process.

3.2.3 Bluetooth Technology. Bluetooth is a technology for wireless communication using the worldwide royalty free 2.4 GHz band. For the communication in indoor areas a cell network is build up to guarantee complete coverage, because data transfer between a Bluetooth receiver and a mobile device is only possible in a distance of 10 meters (so called "Pico-Bluetooth"). These characteristics and the increasing availability as "build in" system in mobile devices, makes it possible to use these system as an indoor positioning tool.
One can imagine an indoor location, where Bluetooth receivers are installed in a cellular network. The raster distance could be something about 10 to 20 meters between each receiver. A person moving through the indoor location, equipped with a Bluetooth communication device in his PDA, takes automatically access to each fix installed Bluetooth element in the indoor location. The Bluetooth master station knows which mobile device is communicating with a fix installed element and also it knows the indoor positions of the fix installed elements. Similar to GSM cells, it is possible to locate the user's position, in the accuracy of a cell size, which is in the order of 10 meters.

3.3 Outdoor Positioning

In the outdoor area positioning tools like DGPS are possible, but more intelligent algorithms are required to provide location aware applications for mobile users. The GPS error characteristics are well known; the shadowing and multipath difficulties are of major concern especially in cities. In general there are two possibilities to overcome these errors: The additional use of sensors supporting GPS-positioning or prediction strategies. To describe this basic approaches an overview is given in the following.

3.3.1 GPS and additional sensors. The main positioning sensor for the outdoor area is GPS, especially differential GPS. Using this sensor it is possible to determine the position within an accuracy of a few meters, which is necessary to provide NEXUS specific services. Presently, a standard Garmin LP25 differential GPS receiver is utilized in the NEXUS project. Using the ALF service (**A**ccurate Positioning by **L**ow **F**requency) provided by the "Deutsche Telekom", the differential mode is realized. Here a correction signal is sent every 3 seconds via long wave from the transmitter station in Mainflingen (Frankfurt) and is available all around in Germany. The accuracy of such systems depends on the distance of the reference station and the GPS receiver position of the mobile user. Research results show, that the necessary accuracies could be achieved and that the results are very promising. In the test area "Bohnenviertel (Stuttgart city centre)" (see Fig. 4) accuracies of about 3 meters were achieved and maximum errors of about 10 meters occurred in some points.



Accuracy	
σ_{pos} (Stuttgart-Bohnenviertel)	± 3 m
GDOP	3,2
max. deviation of desired trajectory	10 m

Fig. 4. Test area Stuttgart "Bohnenviertel" (Stuttgart city centre) and achieved positioning accuracy

The accuracy obtained under such test conditions is sufficient for location aware applications in outdoor areas. But especially in cities the satellite visibility is a major problem and cannot be neglected a priori. Narrow streets and high buildings will shadow the satellite signal in some cases. To bridge these outages information of additional sensors is required. Therefore it is important to employ different additional sensors, working independent, e.g. digital compass and pedometer. Data from these sensors could provide position information for locations without GPS signal. With the optimal integration of GPS and additional sensors the positioning accuracy and reliability is increased significantly.

3.3.2 GSM Network. NEXUS users are equipped with different sensors and communication devices, to allow spatial awareness and access to information sources. In the next chapter the communication environment is described using GSM (**G**lobal **S**ystem for **M**obile Communications) as communication device, which is a standard for digital wireless communication in Europe and other countries. The GSM service is realized as a cellular network and can serve as indirect positioning tool. If a mobile user moves through the environment, the GSM provider knows in which cell he stays at the moment. If this information is provided to the user, it could be used as position information, because the coordinates of each GSM cell centre are well known. Using GSM as indirect positioning device, the accuracy information will be only in the category of 100 meters. But sometimes these accuracy will be enough, especially in case no additional position information is available.

4 COMMUNICATION ENVIRONMENT

In the NEXUS environment the use of a heterogenous communication environment is important, because no migration to a homogenous communication environment is possible. For this case NEXUS will be able to handle all network technologies to give the best communication support (see Fig. 5).

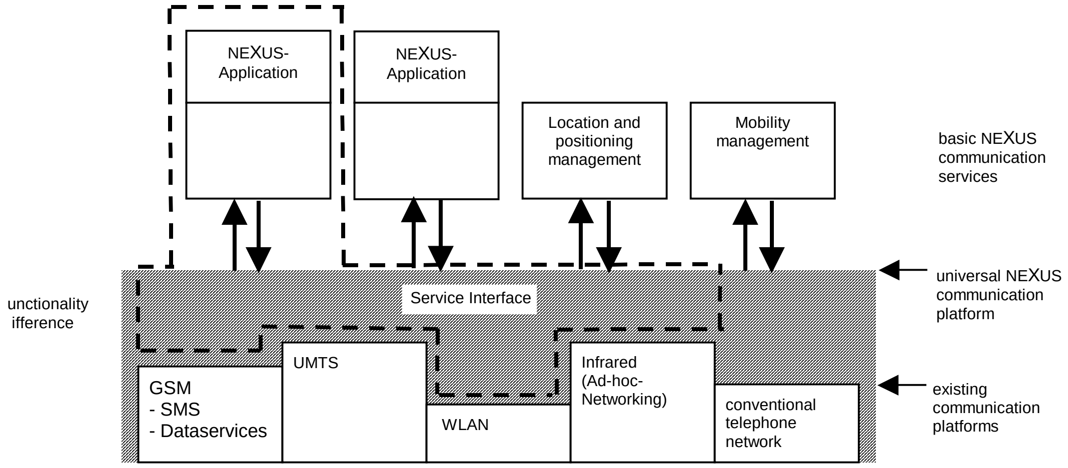


Figure 5. Existing heterogenous networks and NEXUS communication platform

According to the IEEE 802.11 Standard for local networks, IrDA a device for infrared data transmission (e.g. between PDAs) and fast IrDA technology are used for data transfer and access to the WWW, but also other LAN technologies are possible. A further tool for data transmission is a wireless LAN, based on radio wave technique, which is able to provide higher data transmission rates. Additionally Bluetooth provides an inexpensive device for such data transfer. In case of a wide area network (WAN) the mobile communication could be utilized, especially the GSM technology (Eberspächer & Vögel 1998).

4.1 Wireless Communication

A main task in the NEXUS environment is wireless communication, to get the necessary information, but also to communicate with other NEXUS stations. For realizing that support, mobile devices are equipped with tools for wireless communication.

Manufacturer of communication devices like mobile telephones or PDAs are preparing their products increasingly with additional short distance communication technology e.g. like the Bluetooth technology. The advantage is, that in near future a quasi standard will arise and the amount of devices, supporting this technology, will increase more and more.

Nowadays a standard wireless communication for PDAs does not exist. The use of GSM technology is possible, but this is also an external device and the data rates for transmission are restricted. Some devices dispose an IrDA link, but the handicap of this technology is the visibility between emitter and receiver; also the data transmission rates are not very high. In future the transmission rates of present communication devices will speed up, but as nowadays a unique communication platform will be missing. In case of NEXUS a universal communication layer is required to give best support. To overcome these functionality difference NEXUS must provide a service interface (see Fig. 5).

4.2 Access to Information Sources

The main effort of NEXUS is to provide information to the users. In order to supply actual and selective data, access to different information sources is required. As mentioned the access will be wireless and the time for data transmission must be as short as possible. In general the access to information sources will happen in different ways. Dependent on the communication environment and the NEXUS device, a user will dispose of different data transfer rates. To provide information in acceptable transfer times, suited to interface type and requirements of the user, the data must be available in different representations. Depending to the user's profile NEXUS must decide which information in which representation level should be transmitted. For example alphanumeric representations can be provided faster than its graphic representation, because of data amount. Also it is possible that a user's device only is able to display information in alphanumeric mode.

5 CONCLUSIONS

In general NEXUS is a platform that supports location aware applications. On the basis of these ideas, a prototype of the NEXUS station is being developed within the ongoing research group. This prototype will give support for a few selected applications. It will serve for demonstrations and will be available in two years.
Upcoming tasks will deal with implementation of different sensor systems for positioning in outdoors and indoors. But not only position information as a prerequisite for spatial aware applications is required, also object recognition is needed to provide information services. Moreover different methods and tools must be evaluated and implemented, e.g. pointing devices and image interpretation for object recognition.

REFERENCES

Ahn, S.J. and Schultes, M., 1997. A new circular coded target for the automation of photogrammetric 3D-surface measurements. In: Optical 3-D Measurement, Wichmann Verlag, München, Germany.

Bernecker, B., 1999. Krümmungsbasiertes Map Matching – ein Verfahren zur Positionsbestimmung , Diploma Thesis Nr. 425, Institute for Photogrammetry, Stuttgart.

Bluetooth, 2000. http://www.bluetooth.com

Czommer, R., Möhlenbrink, W., 1999. Multi-sensor Map-Matching Concepts for Positioning of Road and Rail Vehicles, Proc. International Workshop on Mobile Mapping Technology, Bangkok, Thailand, pp.4.4.1- 4.4.6.

Eberspächer, J. and Vögel, H.-J., 1998. GSM Switching, Services and Protocol, B.G. Teubner, Stuttgart, Germany.

Hohl, F., Kubach, U., Leonhardi, A., Rothermel, K. and Schwehm, M., 1999. Nexus – an Open Global Infrastructure for Spatial-Aware Applications, Proceedings of the 5th International Conference on Mobile Computing and Networking, Seattle.

Open GIS Consortium, 2000. Inc. Open GIS Consortium, http://www.opengis.org

Want, R., Falcao, V. and Gibbons, J., 1991.The Active Badge Location System, ACM Transactions on Information Systems, Vol. 10, No.1, ACM Press, pp. 91-102.

Rosenblum, L., 2000. Virtual and Augmented Reality 2020, IEEE Computer Graphics and Applications, Vol. January/February 2000.

WAP Forum,1999. Wireless Application Protocol Forum, http://www.wapforum.org