

# Location-based *ad hoc* Message Propagation Using Wi-Fi and 2G/3G Networks

**The prevalence of Wi-Fi hot spots in cities has formed the backbone of a converged wireless platform for mobile users. The need for location-based advertising, reducing the cost of advertisement, and higher transfer speeds, has fuelled the birth of *ad hoc* incentive-based advertising. In this article, we propose an advertisement protocol that employs policy management to control the propagation of messages within a given mobile region using IEEE802.11. With this approach, the mobile user forwards the message (which is bandwidth intensive) to another mobile user via IEEE802.11, who may be rewarded for forwarding it. Nevertheless, the minimal bandwidth activities such as security, propagation co-ordination and accounting, are managed by the licensed mobile network operator. The proposed framework benefits both the advertiser and the end users.**

- secure software from Fon which will turn home Wi-Fi networks into hot spots which anyone within its range can use to connect to the Internet for a fee;
- it will allow hot spots and bandwidth to be shared and used by any other members without charge;
- users will pay to connect to the FON network and will not share their own networks.

According to the Audit Bureau of Verification Services<sup>3</sup>, advertisers spent 60% more on banner advertisements, classifieds and sponsored links on-line in the year to 31 December 2005, than in 2004. If growth continues at this rate, on-line advertising is set to overtake established media such as radio and even magazines in the US\$10.3 billion advertising market.

Advertising is not new and can cause much irritation in the wired Internet; it is now gaining ground in the mobile world<sup>4</sup>. Currently, much of the advertising is done through unsolicited e-mails, Web pages, (freeware) applications and spy ware programs, etc. We refer to them as spammers. Regulations for punishing spammers vary in each country<sup>5,6</sup>. In the mobile world, it can be much more costly and difficult for the spammer to achieve similar results. For instance, the software platform on mobile phones tends to be robust in enforcing strict policies on third party applications when using the mobile phone's communication services. This also curbs viruses and worms, though the increasing functionality and flexibility in the device platform may change this in the near future. Communication services include multimedia messaging and wireless application protocol (WAP) portals that are connected via a wide area network such as general packet radio service (GPRS), where all communications (and accounting) are centrally managed. It is currently expensive for an advertiser to send multimedia message service (MMS) advertisements to a large number of subscribers. In addition, the advertiser may want to target certain groups of people at certain locations. Though this is not impossible technically, it can be very

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## Introduction

In the UK, there are city-wide Wi-Fi roll-outs from spring 2006. The first phase will see hot zones set up in Edinburgh, Leeds, Manchester, Birmingham, Nottingham, Oxford, Cambridge and three London boroughs (Islington, Kensington and Camden). It is expected that the new wireless Internet network brought by The Cloud will reach more than 4 million people<sup>1</sup>. With wireless networks expanding at this rate, it encourages many hot spot providers to look into ways to increase revenue from their services. Mainstream players attempt openWi-Fi (e.g. 'free' Internet access but bundled with banner-based advertising) with Google, Skype and leading venture capitalists investing in a new user-run network of Wi-Fi hot spots. Fon (the largest Wi-Fi community in the world) would allow users with not just laptops, but also mobile phones or the latest portable gaming devices to share wireless connections offered by other Fon users<sup>2</sup> via three sharing options:

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costly and cumbersome as compared to wired Internet spamming. Ultimately, would users want to receive adverts (or spam)? If so, what incentives are there for them to view them? Reports in a survey of wireless users indicated that majority of the users are willing to receive advertising on their devices if some sort of incentives are offered.

We introduce techniques to manage controlled advertising among users in a specific area. We call it 'regulated and incentive-based advertising', where nodes in an *ad hoc* network (see Figure 1) receive advertisements in relation to their vicinity and user interest and their willingness to earn incentives.

The nodes can choose to forward these advertisements based on their willingness to earn incentives, available portable power, network status, etc. We aim to ensure that each node has full control of incoming and outgoing advertisements adhering to security and privacy policies and preventing unsolicited advertisements. Nodes forwarding advertisements and/or viewing them will be rewarded by the advertisement's originator. There are many ways in providing incentives for nodes in an *ad hoc* network, but our primary focus is on the advertisements protocol. We introduce a simple and cost-effective framework that benefits both the advertiser and the end user.

## Background

### Overview of high-speed wireless networks

In the UK, most mobiles are WAP-enabled or operate on the 2.5G platform, namely GPRS. Unlike GSM, GPRS is an 'always on' type of (IP) connection and can transfer data at higher speeds (theoretical maximum

of 171.2 kbit/s, when using all eight time-slots simultaneously). It is also possible to have data transfer and a voice call at the same time. However, GPRS charges are still very high, typically £2 per MB, and practical speeds are usually lower (~48 kbit/s). Other marginally higher speed 2.5G technologies such as high speed circuit switched data (HSCSD) and enhanced data (EDGE) rates for GSM evolution are also costly and not widely available in most countries. The recently adopted 3G technology such as wideband code-division multiple access (WCDMA), which offers up to 2 Mbit/s data rates (typically ~384 kbit/s in practice), is expected to supersede 2.5G technologies. Presently, the 3G coverage is limited and likely to be very costly for data transfers in the near future. Looking ahead, 3.5G networks, namely high-speed downlink packet access (HSDPA), offer higher speeds than WCDMA (i.e. a factor of five times or more downlink and shared uplink bandwidth). However, even with 10 Mbit/s downlink and 384 kbit/s uplink, it is still not as good as speed achieved in IEEE802.11 networks.

The IEEE802.11 family of technologies were developed by IEEE for LAN networks, as well as other standards dedicated to providing wireless services such as IEEE802.15 for PAN networks and IEEE802.16 for MAN networks. Today, 802.11 a/b/g/n standards are commercially available in the market using the 2.4 GHz and 5 GHz bands and providing very high data rates (~54 Mbit/s). Upcoming IEEE802.11n is anticipated to support connections at even 200 Mbit/s using a wider channel and multiple-input multiple-output (MIMO) antennas. Two modes are supported in IEEE802.11, BSS and IBSS. In independent basic service set, also known as *ad hoc* mode, devices form a simple interconnected network offering very high data rates at no cost. It takes less than a second to transmit 1MB of data over an IEEE802.11 a/g network, compared to GPRS which may take up to a minute.

According to Ovum<sup>8</sup>, Wi-Fi is considered by many fixed telecommunications operators as the first step towards fixed-mobile convergence. Wi-Fi services are gaining popularity and have found their way into the service portfolio of operators such as Korea Telecom and BT. These carriers prefer bundling Wi-Fi services with broadband or cellular services, which allow them to differentiate their service offerings to retain customers and find alternative revenue streams to offset their declining revenues from voice services. Korea Telecom is providing various Wi-Fi services under its Nespot brand, and BT is offering wireless

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access to the Internet via its BT Openzone services in hot spot zones.

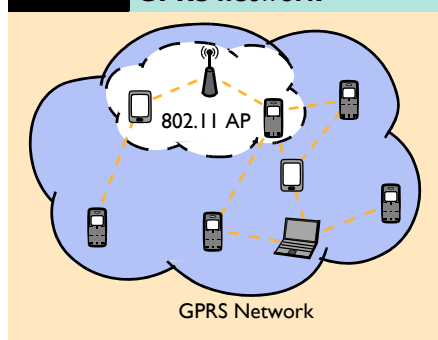
We propose a new service framework that uses the benefits of both Wi-Fi hot spots and 2.5G/3G technologies. Our framework uses IEEE802.11 IBSS to connect two devices temporarily and enable them to exchange data at very high rates (and at no cost). GPRS is only used as a trusted network for device authentication, verification of digital signatures, billing and accounting, etc.

### Mobile advertising

According to a report on the Japanese market by Flytxt<sup>9</sup>, the Japanese mobile marketing spend in 2004, was estimated at around US\$177m, up 77% from 2003. This trend is likely to spread around the world. Informa estimate that the global market for mobile entertainment is set to reach US\$42.8bn by 2010<sup>10</sup>. Wireless advertising will play a key role in these emerging markets.

To date, there are several mechanisms to advertise messages/content to mobile users. An advertising mechanism that uses GSM to send advertisements to mobile users already existed few years ago. For instance, an advertising message is played before the connection of each phone call. Users who have subscribed to listen to such advertisements, have to listen to the advertisement before the call is connected, in return for the first  $x$  minutes of the call being free. Usually, such adverts are no longer than 15 seconds. Incentives are targeted at mobile users who are not in a hurry and are willing to sacrifice some time before their calls are connected, in return for free call minutes. However, this method is expensive for advertisers as advertisements may not necessarily target the right customers.

**Figure 1** IEEE802.11 *ad hoc* networking with centrally managed GPRS network



## Ad hoc Advertising Approach

We first present a practical scenario that will address the need for a low cost, location-based advertisement protocol. Imagine a user with a mobile device (e.g. phone) with connectivity to more than one network (such as GPRS and Wi-Fi) in a busy shopping area. Their Wi-Fi enabled phone connects to the local shopping network and receives multimedia rich advertisements (or video messages) relevant to that user. This can be done through personalised policies discussed later. One such policy determines their willingness to be interrupted to view the message. The graphic content would be similar to those on TVs and with interactive capabilities, but at a much lower visual resolution. Let us assume the message has a lifetime of an hour and a range span of 1 km<sup>2</sup>. Here the user's willingness to view/interact is proportional to the incentives the user is offered in return for agreeing to be interrupted. Incentives are credited to their account only after they view the entire message. Another policy could determine the device's willingness to forward the message to nearby (Wi-Fi) devices that are not within the range of the message originator. Successfully forwarding the message to a device without a duplicate entry of the message would credit additional incentives to the message forwarder. The message would expire when it reaches its lifetime and/or range span. From the advertiser's view, all co-ordination and accounting is done over the GPRS network, using minimal bandwidth, while the bulk advertisements are sent over Wi-Fi, at low cost (but incurring power costs in the case of Wi-Fi). From the users' perspective, they are rewarded in the form of incentives to receive and/or forward advertisements.

For most users, it is likely that the location-based message would be of more interest to them, than a mass broadcast. For instance, the network operators can be responsible for providing a reliable service (i.e. trusted platform), enforcing fairness, managing incentives and accounting, etc. The users may get incentives from the advertiser for providing customised services through this platform. Such an architecture (and business model) would be extremely cumbersome to build and manage in the wired Internet world. Examples of failed or struggling initiatives include pop-ups, advertising applications such as Gator, Get Paid to Browse, etc. The key problems are (user) hacking, collusion, security and privacy concerns, etc. Based on these experiences, we have devised a robust framework and business model to facilitate the mobile advertising scenario. The next

**preconfigured policy profiles will be employed (by the user) on the device to manage power usage, frequency of user interrupts, thresholds for incentives (for receiving and forwarding), and advertisement relevance**

sections describe the framework aspect in detail.

### Centralisation

There needs to be a centrally owned and trusted advertising authority to manage merchants (or advertisers). Therefore, advertisers would need a pre-arranged agreement with the advertisement authority to enable their advertisement to be verified upon request by each client device. We would need a trusted advertisement client platform (ACP) (e.g. Java application) that can use both GPRS and Wi-Fi capabilities. This distribution can be similar to the downloading of Java games and applications in existing mobile devices over the GPRS network. Java offers a simple and secure platform for application developers to create multimedia-rich applications. It is up to the user to decide and install an appropriate ACP from a trusted provider.

### Advertisement composition

An advertisement is a multimedia-rich video message with interactive capabilities ideally transferred over high-bandwidth links such as Wi-Fi to reduce transmission delays and at no cost (e.g. using 2.4/5 GHz unlicensed spectrum). The advertisement video message would typically be about 1 MB in size, which can be exchanged in less than 1 sec using IEEE802.11a between two devices. For simplicity and for cohesion, we will assume all messages are of Java class type. Each video message is represented by a metadata (i.e. high level description), which is used in the initial handshaking protocol between the sender and the receiver. An example description in XML format would be:

```
<!-- Advert Meta Data -->
<Advert>
  <Originator>
    <Name>BT Shop</Name>
    <Location>Cell ID</Location>
    <Range>1km</Range>
    <Date>25/12/2005</Date>
    <Time>10:10:10</Time>
  </Originator>
  <Forwarder>...</Forwarder>
  <Contact>
    <Address>...</Address>
  </Contact>
  <Description>
    <Type>Shopping</Type>
```

```
<AgeRating>15</AgeRating>
<Gender>All</Gender>
<Size>200k</Size>
<Hardware>Requirements...
  </Hardware>
<Interactive option="Yes">
<Duration>10s</Duration>
</Interactive>
<Incentives>
<ForwardCredit>0-100
  </ForwardCredit>
<ViewCredit>0-100
  </ViewCredit>
</Incentives>
</Description>
</Advert>
```

The originator denotes details of the message creator and its physical origin. Range gives estimate guidance span to which the message would be broadcast. Exceeding the range would result in the deletion or rejection of the message by the device. The relevance of the video message can be gathered from the description tag. Finally, the incentive tag provides information regarding incentives to message viewers and forwarders. We use a policy-driven model to make decisions based on the metadata, such as:

- Does the device have sufficient (or some threshold) battery power to enable Wi-Fi capabilities?
- Is the message relevant to the user?
- What is the incentive threshold for the device?

We envisage that preconfigured policy profiles are employed (by the user) on the device to manage power usage, frequency of user interrupts, thresholds for incentives (for receiving and forwarding), and advertisement relevance, etc.

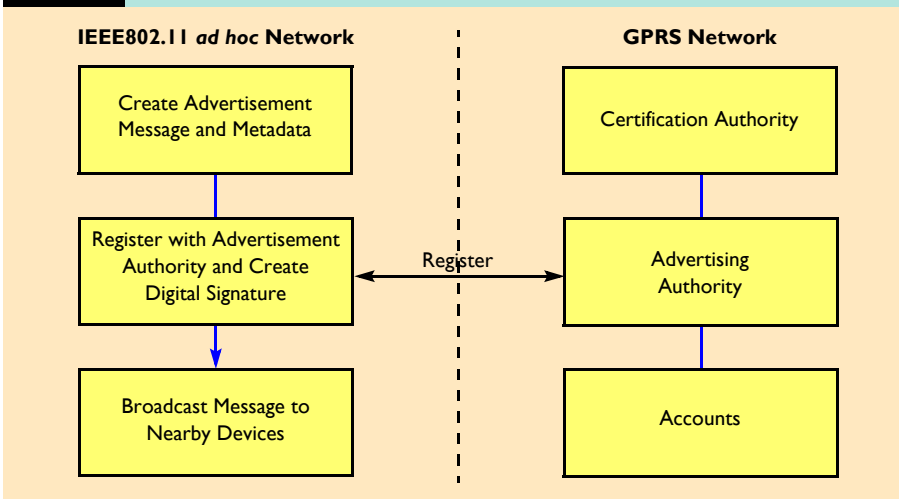
### P2P broadcast

As discussed earlier, we propose the use of IEEE802.11 *ad hoc* mode for the propagation of messages.

We first describe the steps taken by the message originator (see Figure 2), who has an account with an advertising authority:

- create multimedia-rich video message;
- add relevant metadata (in XML) as described earlier;
- originator generates message digest for both metadata and advertisement using

**Figure 2 Steps at the advertiser**



one way hash function – they then encrypt this message digest with their private key, known as a digital signature and appended to the message;

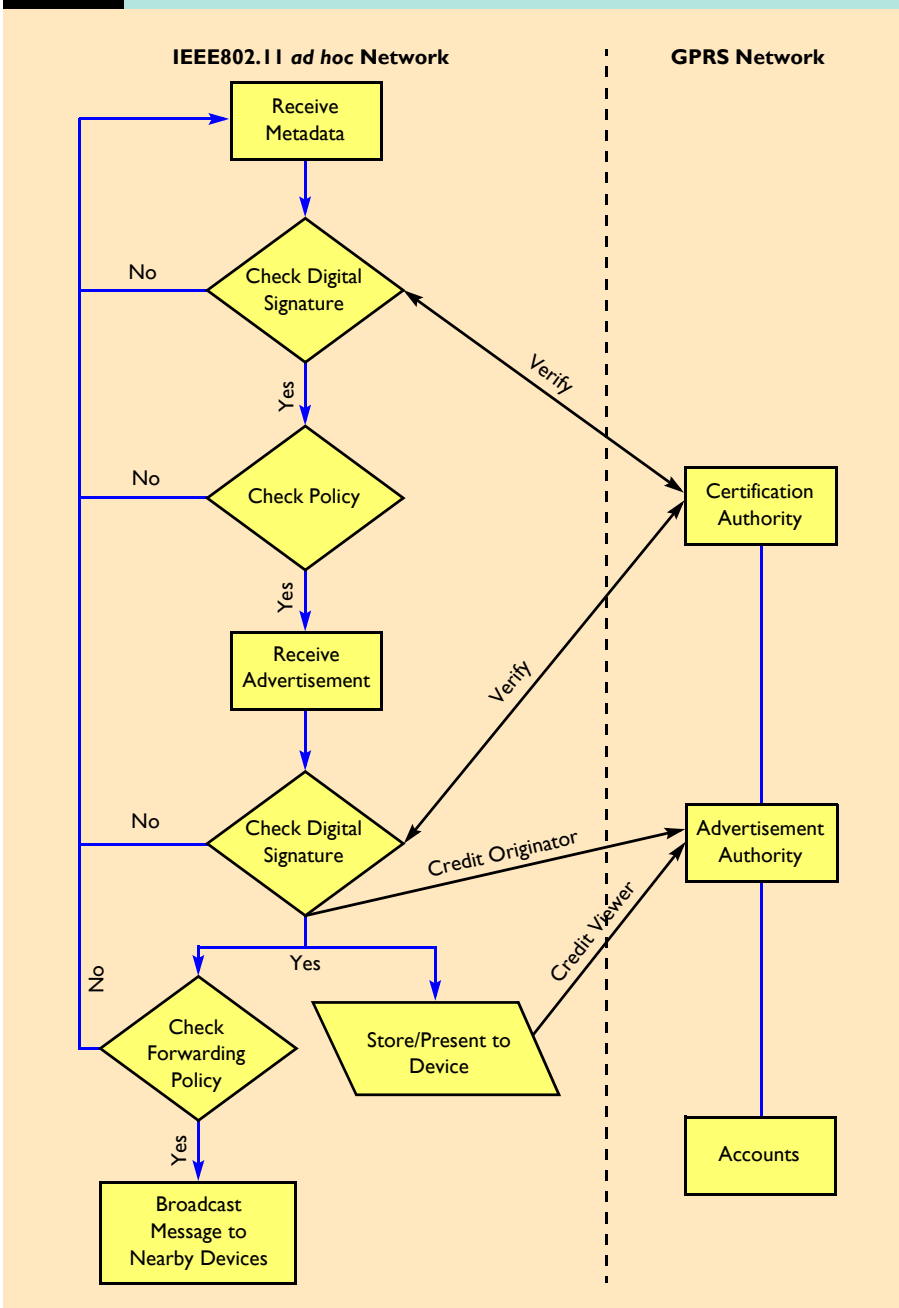
- register advertisement and signature (public) key(s) with advertising authority.

We have introduced digital signatures to ensure that the metadata and message cannot be tampered with by malicious intermediate devices. Therefore, this overhead is essential and devices verify digital signatures using the GPRS network (i.e. a trusted network).

The steps (in brief) at the device (see Figure 3), when Wi-Fi is enabled are as follows:

- originators periodically broadcast adverts via their fixed AP;
- device in Wi-Fi *ad hoc* mode connects to the originator (i.e. AP);
- ACP receives metadata and verifies signature (public keys can be obtained from the certification authority for verification of the digital signature);
- ACP runs the user policy on the metadata;
- ACP downloads the video message and verifies the digital signature;
- ACP checks interruption policy and presents advertisement to user;
- ACP runs the forwarding policy and forwards message to other nearby devices.

**Figure 3 Steps at device**

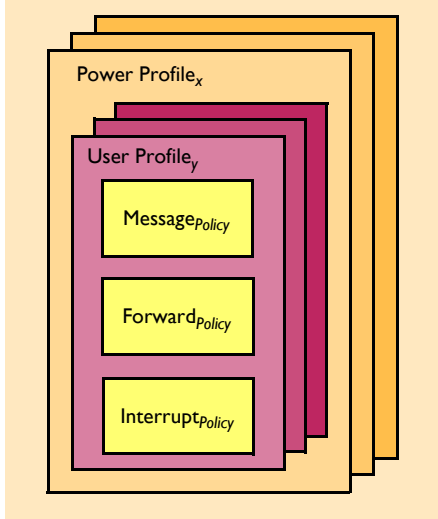


### Policies

We have taken a policy driven approach to manage the preferences, accounts and incentives of both the user and the advertiser. This is analogous to the intelligent power-save feature in today's portables that manages the various hardware components including the display screen and applications. For instance, Figure 4 depicts an approach where multiple user profiles are encompassed by multiple power profiles. In this scheme, the predominant power resource determines the node's level of participation in the proposed advertisement network.

### User policies – message, interruption and forwarding

The message policy matches the user's interest to the message type (e.g. shopping sale advertisements) while the interruption policy determines the level at which the user is willing to be interrupted to view the message. A number of factors, such as

**Figure 4** Policy profiles based on power

viewing credits or power level, can affect the user interruption initiation. Similarly, the forwarding policy ensures that messages are forwarded based on power level, range, etc. For instance, at low power, forwarding may be disabled or require a higher number of credits, set (or override) by the power policy. A sample profile<sub>x,y</sub> (policy) which is matched against the message metadata to determine the optimal choices is illustrated below:

```
<!-- Policy using profiles x,y -->
<Policy>
  <ID>X,Y</ID>
  <Message>
    <Description>...</Description>
  </Message>
  <Interrupt>
    <ViewCredit>0-100</ViewCredit>
  </Interrupt>
  <Forward>
    <ForwardCredit>0-100
  </ForwardCredit>
  </Forward>
</Policy>
```

### Advertiser policies

This policy, located at the provider's advertisement authority ensures that the advertisement creator has some control on the propagation of the advertisement. Each time a credit is given to a node, this policy data is updated. For instance, the number of hops and/or the amount of credits could be managed in this policy, i.e. when the device verifies the advertisements' digital signature, it could also check the advertiser policy to ensure that it has not reached the

maximum number of hops and/or the advertiser has not run out of credits. If so, the device can discard the message.

## Issues and Challenges

### Secure re-broadcast

Once the metadata has been verified and the advertisement downloaded, the node will send an incentive reward message to ask the advertiser to credit the message forwarder. Messages are re-broadcast (or forwarded) if they meet the requirements of the forwarding policy of the device. It is possible to set a condition that credits are only given if a message has been successfully forwarded and viewed by the device. Before re-broadcasting, the device will update the metadata with the forwarder details. A new digital signature is generated and registered with the advertisement authority. For instance, each ACP could use a unique registered private key to create digital signatures. This metadata enables a device to distinguish direct and forwarded messages, assists in testing the time and span validity of a message, and for crediting incentives.

Alternatively, a new digital signature representing the supplemented metadata could be generated by the advertisement authority. If appropriate, the message will be further re-broadcast. The receiving device will send an incentive report to the trusted advertisement authority to enable credit to be given to the forwarder. Preferably, this report will identify the receiving device, the advertisement and the forwarder. To protect against counterfeit incentive reports (and for general security), the ACP should reside on a restricted device platform where it cannot easily be hacked. The incentive report will itself be encrypted, with the unique private key of the ACP which can be provided conveniently through the SIM identification.

### Wi-Fi or Bluetooth

With the availability of Bluetooth in most mobile handsets, users are able to send/forward messages to neighbouring peers within close proximity (~ 10 m range). The messages can be targeted at users in specific locations such as cafés where users can exchange business contacts, etc. It is possible to extend our framework to use Bluetooth instead, for instance, in crowded places (e.g. in a bus or train) where messages can easily be propagated at low range and power. However, we have chosen Wi-Fi instead, offering much higher

bandwidth and range which caters for sparsely dispersed devices. In Ferro and Potorti<sup>11</sup>, spatial capacity is evaluated for IEEE802.11g between 0.1 kbit/s to 400 kbit/s and Bluetooth at 25 kbit/s per m<sup>2</sup>. Therefore, (given power control) IEEE802.11 technologies can theoretically offer much higher transport capacity than Bluetooth. However, Bluetooth's total (operating) power usage is much less than IEEE802.11's. When we consider mobility and density of devices, it is unlikely that Bluetooth's 10 m coverage would be sufficient to successfully propagate large multimedia messages. A typical IEEE802.11 device would give about 50 m coverage and ensure greater speed.

### Balance between power and cost

This largely varies on the device and user's requirements. How much power is the user willing to share? How much control should be presented to match the user's needs? Ideally, we envisage seeing the simplest options and interfaces similar to that presented in modern laptops (e.g. normal, presentation, long life, etc). Well-defined power policies are essential to ensure no/minimal service disruption and maximising user benefits. One approach in saving power is to use the 'always connected' network to relay wide-area information. For instance, devices in GSM cells where there are less likely to be hot spots or other relaying devices could be triggered to power down their Wi-Fi interface. A more complex approach would be for the GSM base-station to inform the device of the number of (advertising) hot spots and Wi-Fi capable devices within the cell. From this, a probability of neighbouring peers could be computed to enable the optimal usage of Wi-Fi energy.

**well-defined power policies are essential to ensure no/minimal service disruption and maximising user benefits – one approach in saving power is to use the 'always connected' network to relay wide-area information**

## IP address management

As mobile devices roam freely in and out of *ad hoc* Wi-Fi range and also in the vicinity of infrastructure mode Wi-Fi hot spots, the issue of assigning an IP address to the device can be challenging. The main criteria we have in designing an addressing mechanism are:

- the ease (speed) of joining and leaving a Wi-Fi hot spot for a device;
- to have low overhead in processing the address, to avoid duplication of addresses;
- to have an address management mechanism to ensure devices free their addresses for reuse;
- to protect the identity of the device.

Currently, each device is equipped with a single Wi-Fi interface and it is not possible to simultaneously run *ad hoc* and infrastructure modes without a modified MAC layer. Assuming this is possible, in *ad hoc* mode there needs to be an automatic IP address management system to enable devices to interact with each other at the application layer.

Briefly, there are numerous addressing schemes proposed for mobile *ad hoc* networking but none of them is well established. There are two main types of addressing schemes.

- **Static addressing**  
In static addressing, the addresses are manually assigned to the device (by either the administrator of the network or a centrally controlled authority). Most routing protocols rely on nodes having a unique address. This scheme requires cumbersome administration and results in poor utilisation of available addresses.
- **Dynamic addressing**  
In dynamic addressing, which can be either centralised or distributed, auto-configuration can be used to prevent duplicate address allocations. An example would be in a fixed IP network where dynamic host configuration protocol (DHCP) uses servers to auto-configure nodes with a topologically correct address as they move. Such functionality could be provided through the GPRS network, where a centralised DHCP server allocates addresses based on the location of the devices in GSM cells.

## Location and span

In the absence of global positioning system (GPS) on the device, which also only works when outdoors, we can compute (through approximation) the location and propagation span by using hop count and/

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or GSM cell ID. Using the latter, the metadata containing the origin of the cell ID and the different cell IDs of devices along the route, can determine the approximate distance from the source to the destination via the GSM network service provider. GSM users can be tracked between 200 m and 1 km. In the former, using hops to determine approximate range can be calculated by monitoring the number of users receiving the timestamped metadata (i.e. similar to time to live (TTL) but with timestamp). A combination of the two can be implemented to achieve a better propagation span.

## Conclusions

Existing mobile phones play a key role in branded content. Brand advertisers are using mobile phones as an opportunity to market themselves in places where consumers are having fun, rather than distracting them. Advertisers need to tailor and distribute content to target specific mobile users so that they are not all bombarded with advertisements. The proposed framework prevents unauthorised spam through metadata certification and policies. We envisage the incentive model and branding to be the key elements in driving mobile advertisement economics.

The concept of wireless advertising is not new, but we have breathed new life into this area by introducing an *ad hoc* incentives-driven approach. Our main contribution is the definition of an advertisement framework that allows advertisements to propagate within a specific region using Wi-Fi. We conclude that there are several advantages in this approach. Advertisements are transferred at a lower cost, in specific regions and at a higher speed using IEEE802.11a/g, which make the present wireless advertisements that are transmitted directly to the mobile user via GPRS pale in comparison. Our approach is not only beneficial for the advertiser to achieve effective localised advertising using an economical medium, but also for the mobile user to gain credits from downloading and propagating the advertisements. With policy management in the mobile device, the advertisements are

propagated to interested parties who are more likely to respond to the advertisement offer. In this way, general customer satisfaction can be maintained because uninterested customers can always choose to unsubscribe from this service.

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## Biographies

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Benjamin Bappu has been a part-time PhD candidate (funded by BT) at Lancaster University, UK, since 2002, after completing his MPhil. He received his MSc degree in Distributed Systems from the University of Kent, at Canterbury, UK in 1999. Prior to that he obtained an Advanced Diploma in Data Communications and Networking in 1997, and a Diploma in Electrical Engineering in 1994, both from Ngee Ann Polytechnic in Singapore. He is currently a senior research scientist at BT's Networks Research Centre. His current research interests are in wireless spectrum optimisation and convergence, and QoS.

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