RTT TECHNOLOGY TOPIC
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Ad hoc networks

In our April hot topic, we summarised how mobile IP will likely evolve as a mechanism for delivering IP address mobility both in wide area networks (macro mobility management) and local area networks (micro mobility management). We showed how mobile IP creates a bridge between GSM MAP networks in which addressing is user specific and IS41 networks where addressing is device specific.

With mobile IP, IP addresses will be tracked by network home and visitor location registers, ie it is functionally tied in to the cellular network (networks).

Appliances that have an IP address embedded on the production line (IP appliances) do not necessarily need to be attached to a network – indeed, such devices can create their own network or ‘virtual community’ on demand – such networks are described as ‘ad hoc’ networks.

The idea of having radios that form their own networks is far from new – back to back working in which PMR radios talk to one another without the mediation of a base station go back to the earliest days of mobile radio. More recently, the European TETRA standard has implemented a ‘direct mode’ protocol in which radios talk back to back, for example to provide instant communications for a group working underground in an emergency, away from surface RF coverage. One radio in the group can be designated as a master, radios can also act as repeaters to provide extended coverage within the group and/or for inter-group communication. PHS in Japan has a similar functionality built in to the PHS access protocol, ie PHS phones can be used in ‘walkie-talkie’ mode although such use has been assiduously discouraged by the PHS network operator community.

Using IP addresses and IP routing protocols in these networks can greatly extend their functionality. Network operators have been traditionally nervous about allowing back to back working fearing a loss of control over users, in particular, losing the ability to bill. Pre-pay however, potentially removes these objections – there is no reason why you shouldn’t allow users to talk to each other directly (radio to radio) even if physically divorced from the network, especially if usage involves the expenditure of pre-loaded credit in the transmitting and receiving device. Prepay in effect is a distributed billing technique.

The use of IP routing protocols therefore potentially opens up new revenue opportunities – it also has benefits in terms of increasing the coverage footprint, ie devices can act as routers – routers can act as repeaters.

The figure below is a simple example of an IP based zone routing protocol.

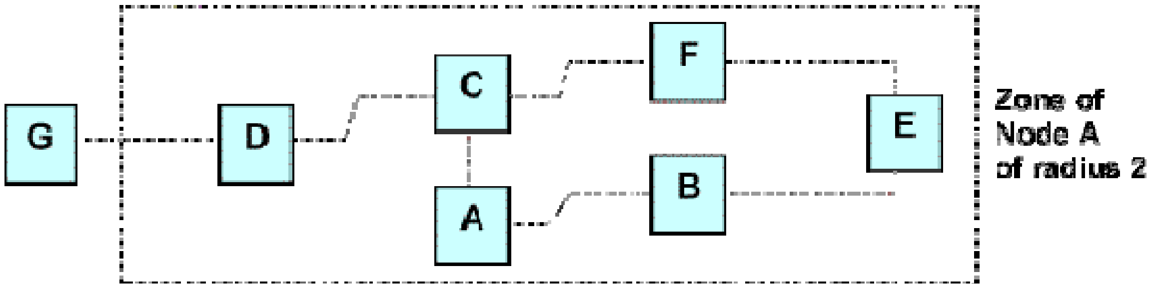

Fig 1

The box defines a zone in which the minimum distance from any device to any other device is never more than 2 hops. Nodes B through F are within the routing zone of A, node G is outside A's routing zone.

Peripheral nodes are nodes whose minimum distance to the node addressed is exactly equal to the zone radius, eg in the example above, nodes D, F and E are A’s peripheral nodes.

This provides an efficient basis for providing inter-zone routing using a process known as ‘border casting’.

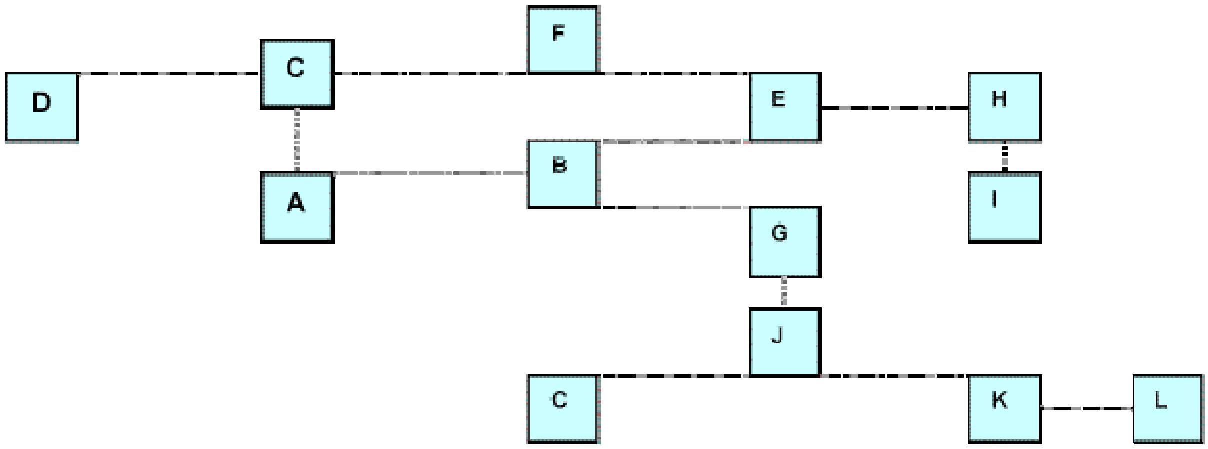

Fig 2

In this example, Node A has a datagram to send to node L. We assume a uniform routing zone radius of 2 hops. Since L is not in A’s routing zone (which includes B, C, D, E, F and G), ‘A’ bordercasts a routing query to its peripheral nodes, D, F, E and G. Each one of these peripheral nodes checks whether L exists in their routing zones. Since L is not found in any routing zones of these nodes, the nodes bordercast the request to their peripheral nodes. G bordercasts to K which realises that L is in its routing zone and returns the requested route (L, K, G, A) to the query source, A.

Using IPV6, a zone routing protocol can then be built both for inter-zone and intra-zone routing using the destination address (the 32 bit IP address of the destination host), the next hop address, the next but one hop address and so on, the number of hops is described using a 4 bit hop count field – the complex routing description becomes the basis for the intra-zone and inter-zone routing tables.

These routing protocols can then be refined into pro-active or reactive protocols. Proactive protocols continuously evaluate the routes within the network. When a packet needs to be forwarded, the optimal route is already known. This has the advantage of minimal routing delay. It would be used for example in a user group in which ‘on to channel’ access times were critical. The disadvantage is that the protocol absorbs network bandwidth. A reactive protocol invokes a route determination procedure on demand – implicitly this will involve a channel set up delay which will be variable and will be ill suited to real time or time critical applications. However we can use local memory bandwidth in the IP appliance to give us the benefits of pro-active protocols (fast and deterministic channel access) without incurring high signalling bandwidth overhead. To do this we use route discovery. In route discovery, the source node broadcasts a route request packet. Each node hearing the request passes on the request and adds its own address to the header. The forwarding of the route request propagates out until the target of the request is found. The target then replies. All source routes learned by a node are kept in a route cache. When sending a packet, a note will only do route discovery if no suitable source route is found in the local cache memory; ie memory bandwidth has been used to reduce the signalling bandwidth overhead. As a node overhears routes being used by other nodes for route discovery or route maintenance, the node may insert these routes into it’s route cache – this is called ‘promiscuous snooping’.

There are many refinements possible over and above these basic intra-zone and inter-zone routing protocols – any or all of the protocols can be used either to transparently fill in the gaps between base stations and/or extend the coverage of an instant self-contained ad hoc network. For example clustered based routing protocols – a cluster is a group of mobiles which is ‘clustered’ round a base station or in a self-sustaining cluster (sometimes also described as a ‘cloud’, though clouds tend to be more mobile than clusters). A cluster head is elected for each cluster to maintain cluster membership information (a kind of club membership directory which includes access and membership rights) – this sort of optimisation can improve the scalability of the protocol (avoiding flooding and address storms).

The scalability and stability of routing protocols can be measured and described in terms of convergence. **Convergence** describes the condition in which a state of equilibrium is approached in which all nodes of the network agree on a consistent collection of state about the topology of the network and in which no further control messages are needed to establish the consistency of the network topology, ie a steady state condition. **Convergence time** is the time required for a network to reach convergence after an event (typically the movement of a mobile node) has changed the network topology. Other key performance measurements in ad hoc networks include the **distance vector** (how many hops to store in the routing header), **goodput** (the total bandwidth used less the protocol overhead), **laydown** (the relative physical location of the nodes within the network), the **mobility factor** (the relative frequency of node movement compared to the convergence time of the routing protocols, and the **security parameter index** (the security context between defined router pairs). **Payload** is the description of the actual data within the packet.

Which brings us to one of the intriguing opportunities when we come to qualify the use of IP routing protocols in mobile radio networks – an IP packet can be (more or less) as long as you want. As the packet gets larger, the IP address overhead reduces as a percentage of the payload. A typical PTT (press to talk) transaction on a mobile radio is several seconds – the IP header overhead on such a transaction is (more or less) trivial. Longer transactions can include **IP Jumbograms** – a jumbo payload is defined as a payload between 65, 536 and 4, 294, 967, 295 octets!. IP datagrams can therefore deliver exceedingly impressive 'goodput'. As we have already described in earlier hot topics, IPV6 also provides us with the ability to prioritise and discriminate, which in turn can be used to define on to channel access times (less than 250 milliseconds being the PMR industry's legacy benchmark). IP address and routing protocols therefore provide a very elegant and flexible mechanism for managing mobile networks including ad hoc self-configurable networks.

Back to back working can be easily enabled both in PMR and cellular networks opening up new revenue opportunities in public access (PAMR) or cellular applications when combined with pre-pay methodologies. It underlines the likelihood that wireless IP appliances will become increasingly pervasive, and that the manufacturers of such appliances will likely be increasingly advantaged.

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