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Technical Report

Rapidly Deployable Radio Network ATM/IP Analysis

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The rapidly deployable network is an integrated mobile networking system (see Figure 1). It supports mobile switching nodes, interconnected over point to point radio frequency links, and supports applications with both Internet protocol (IP) and asynchronous transfer mode (ATM) communication services. The RDRN system can also interoperate with wired infrastructure over fiber optic links and satellite systems over radio frequency links. RDRN is a self organizing mobile network.

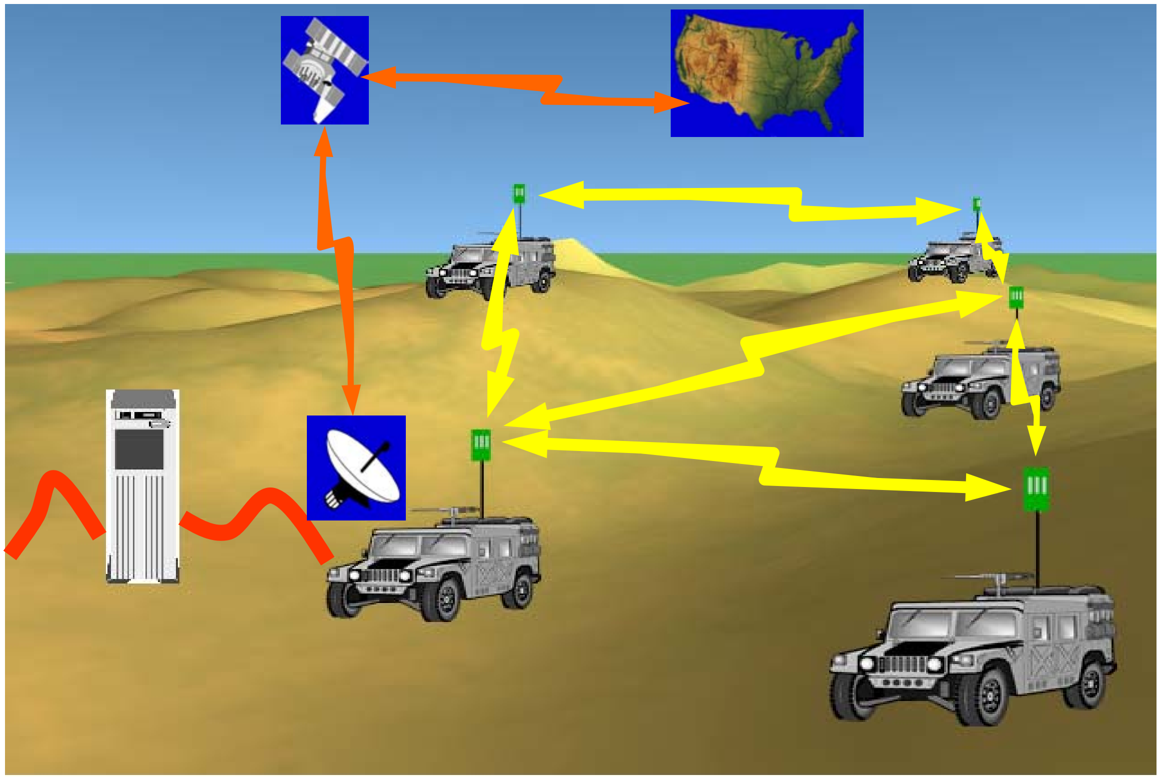

Figure 1 illustrates the Rapidly Deployable Radio Network. RDRN consists of mobile nodes that form a back-bone network. The mobile network can interconnect with wired services as shown on the left.

When RDRN was first proposed, the Internet protocol (IP) offered ubiquitous interconnectivity between a multitude of applications. Asynchronous Transfer Mode (ATM) offered the ability to shape and control traffic flows in a low bandwidth wireless network. Hence, RDRN combined both ATM and IP in the switching nodes; ATM providing traffic shaping and IP providing interconnectivity. An RDRN switching node contained a software ATM switch, multiple virtual ATM devices and perhaps some real ATM devices. The real ATM devices would interconnect to fiber optic networks. The virtual ATM devices would connect to wireless links. The overall software architecture is shown in Figure 2. As ATM cells arrived at a switching node, they could either be switched through the software ATM switch and rerouted back out a different port or be collected into a IP package and forwarded to the IP processing layer.

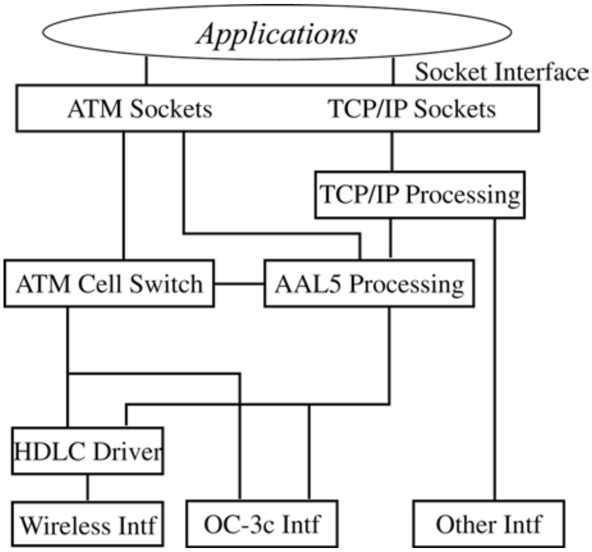

Figure 2 illustrates the RDRN software structure.

In the IP processing layer, packets could either be routed through a normal IP routing mechanism or collected and sent to a higher level such as UDP, TCP and other applications.

Using this combination of ATM and IP seemed a reasonable idea. ATM provided traffic shaping and quick access to link capacity due to the small cell size and IP provided interoperability with numerous operations. However, questions continuously arose as to the efficiency of ATM, particularly over low bandwidth wireless links. There were additional concerns about the delays induced if only larger IP packets were sent over the RF links. This paper attempts to illicit some of the trade-offs between using ATM and IP protocols and some recommendations for future mobile networking systems.

In Figure 3, we show the efficiency of sending different size packets over an ATM only link. Packet sizes are shown from one byte through 8,192 bytes. The analysis shows for very small packets below 32 bytes, ATM is, of course, very inefficient because you must send the entire 48 byte payload plus 5 byte header. For packets between approximately 48 bytes and 256 bytes, ATM is between 60-80% efficient. Above about 512 bytes, ATM reaches its maximum efficiency of about 90%.

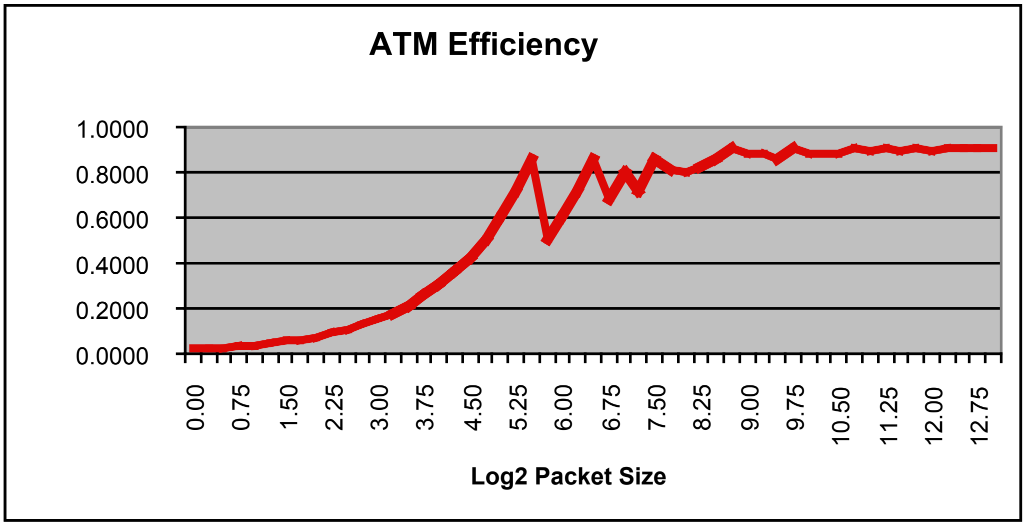

Figure 3 shows the efficiency of ATM versus packet size.

Figure 4 shows IP efficiency for the same packet sizes. Because IP packets can be variable in size, we see a more gradual increase in efficiency up to about 90-93% at 512 bytes. We assume a MTU of 512 bytes. Of course, for very small packets the fixed size of the IP header dominates the efficiency calculation. For very large packets, the overhead of the IP header is amortized over the larger number of bytes and IP efficiency is greater than ATM efficiency. Figure 5 shows an overlay of the two efficiency curves.

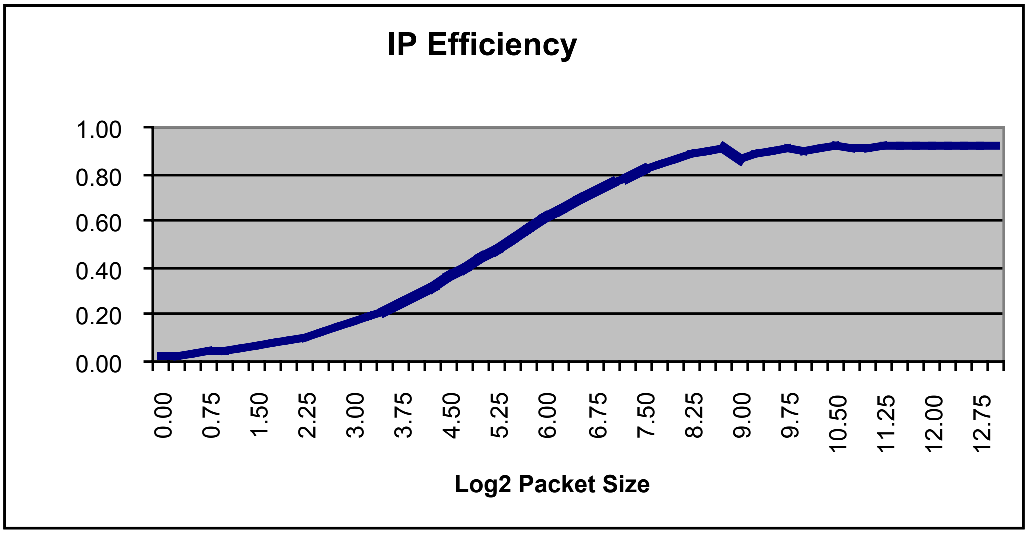

Figure 4 shows the efficiency of IP versus packet size. This chart assumes a MTU of 512 bytes.

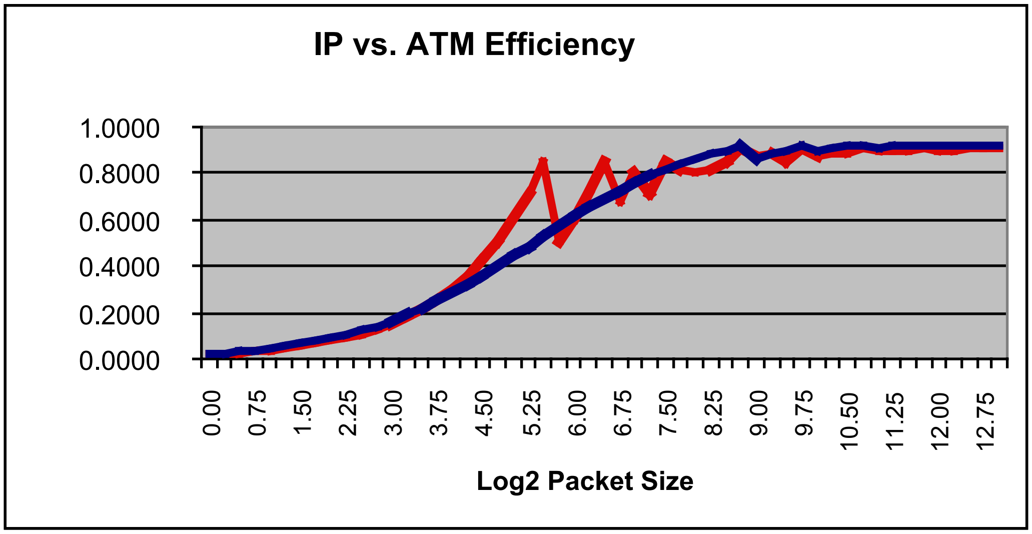

Figure 5 compares the efficiency of ATM to IP over packet sizes from 0 to 8192 bytes.

An approach to obtain the best of both worlds, the smaller header slides of an ATM cell with the variable packet size of an IP packet, one could conceive of an IP circuit identifier at the beginning of an IP packet. If this IP circuit identifier were, say, a 4-byte value, then you get an efficiency curve shown in Figure 6. In this case, even for small packets, we obtain reasonable efficiency that surpasses both ATM and IP, and the efficiency approaches a value of 1 for very large packets. The concept of a circuit identifier introduces state at each end of the link that must be maintained and managed, but this is not different from the IP header compression that occurs in a SLIP or PPP link.

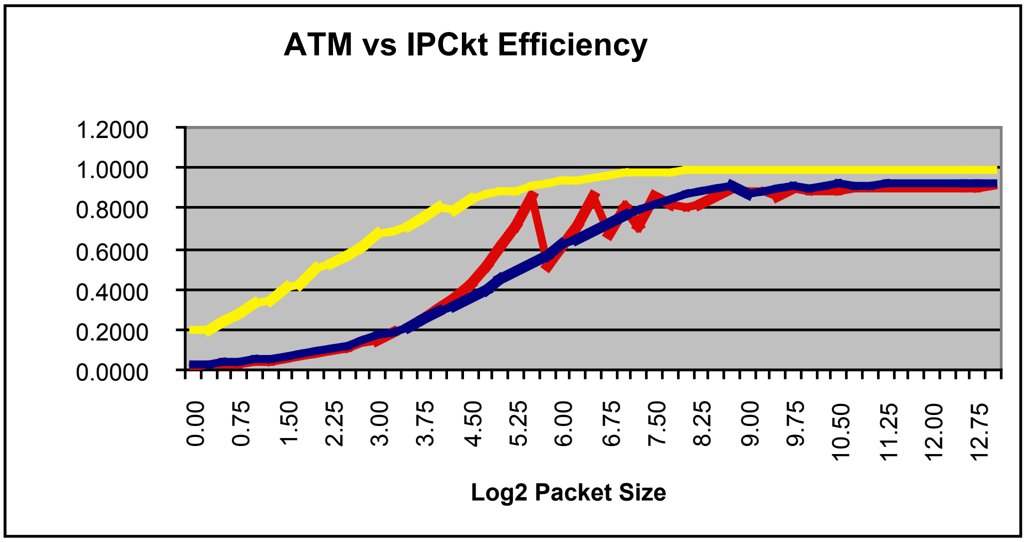

Figure 6 compares the efficiency of an IPCircuits approach to conventional ATM and IP packets.

ATM circuits do not appear to have significantly higher efficiency over IP packets for message sizes from one byte to 8192 bytes. However, packet sizes from 32 bytes to 128 bytes are highly probable in mobile networks and particularly, defense oriented mobile networks. Example applications are telnet, which sends a single packet per character typed, and situation awareness messages**.** The introduction of IP circuit identifiers could significantly increase efficiency in wireless networks and the management of these IP circuit identifiers, the appropriate protocols, associated state, and a dynamic mobile network is a future research problem.

An important characteristic of defense mobile networks is the delay in sending high priority messages through the network. An advantage of ATM technology is that, independent of packet size, time to transmit the first cell of a high priority message on the wireless link is at most one cell time. Figure 8 shows the delay in milliseconds for packet sizes from 1 byte to 8192 bytes assuming a one megabit per second radio frequency link. The red line indicates the average delay for an ATM link. The delay for an IP based link will vary as shown with the blue line based on the maximum transmission unit (MTU) of the interface. In the figure, we have assumed an MTU of 512 bytes. Hence, the IP delay peaks at a packet size of 512 bytes. Then the average delay decreases as the packet size is between 512 and 1024 bytes (the reason for this is half of the time you will have a 512 byte packet ahead of you which you must wait for and half of the time you will have a smaller packet ahead of you). As the total message size reaches 8192 bytes, the average delay the next packet experiences goes to an average of 2 milliseconds. For comparison purposes, we also include a graph for fixed size packet of 96 bytes that has an average delay of just under 1 millisecond.

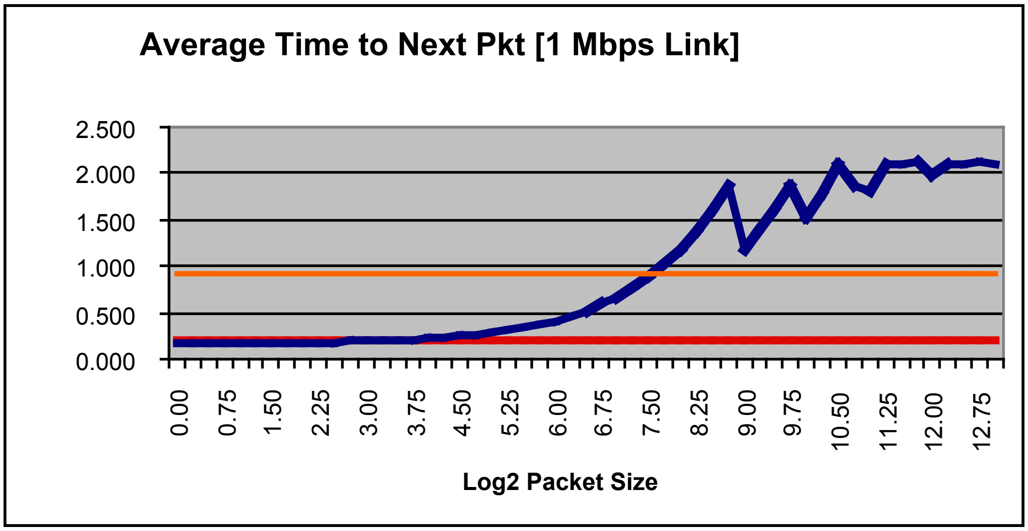

Figure 8 shows the average waiting time at the transmitter for a high priority message.

It would also be useful to measure the effects on a single, high priority flow through a network where there are additional flows going through the same network. In the ATM case, the variants introduced at each node will be relatively small since all the cells are the same size and a high priority flow will always go to the head of the line. In an IP based network, the variants will increase more rapidly because of each switching node. The size of the packet at the head of the queue, that is, the packet being transmitted, will have more variable size and hence the variance will increase.

In summary, for multihop networks short packets or cells will reduce the average delay to the next opportunity to insert traffic and short packets and cells also will reduce the delay variants as the prime packet goes through multihop networks.

Conclusion

To conclude then, ATM cells offer lower average queuing delay to high priority traffic. For short messages, ATM is only slightly less efficient than IP due to the shorter ATM header. Hence, for shorter messages the shorter ATM headers increase efficiency. For longer packets, there is an increased delay variance through a multihop network as high priority traffic must wait at each node for the packet currently on the link.

However, conventional ATM signaling and state maintenance is too complex for a highly mobile network. Circuit set up requires processing at each hop and end-to-end communications. It is extremely difficult to maintain circuit state in mobile switching nodes and the interactions with the Internet Protocol through Classical IP (SEAL IP) and ATMARP are complex.

Our recommendation is to consider radio frequency based mobile networks to use a small fixed packet size or small segment size, perhaps with a circuit identifier at the beginning similar to that used in SLIP and PPP. Future work should be invested in exploring methodologies for rapid flow setup and state maintenance, perhaps along the lines of MPLS.