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Tactical Military Communication Networks of the Future

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ABSTRACT

Military communication has the added dimension of mobility and bandwidth conservation. This paper deals with the necessity of advanced concepts of communicating images, data and fax in addition to voice as dictated by the command and control requirements. The Integrated Services Digital Network as applied to tactical network of the future is presented. The topics of routing, encryption, mobile access, digital links are briefly covered. The importance of standards of CCITT and contemporary techniques like B-ISDN, cellular radios are discussed. The relevance of network management and its main features are brought out.

1. INTRODUCTION

Military communications is the most important aspect of the military operations, just as important as supply lines for food and ammunition. Without communications, a field commander cannot get to know the battlefield situation and hence will not be able to command the operation. Modern wars are fought with weapon delivery system, controlled and guided by high speed computers, with the enemy tracking the movements using sophisticated equipment like radars, night vision equipment, Remotely Pilotted Vehicles (RPVs) and the like. The information flow from the very frontiers of the theatre of war in the form of voice, data and images should reach the decision making authorities in reasonable time, much before its currency is lost. Such real-time requirements impose severe constraints on the communication network. Also tactical communication networks are mobile, requiring network itself to be moved from time-to-time based on progression of the battle, mobility due to gypsy subscribers, or subscribers on the move. Further tactical communication networks are highly vulnerable, being identified as the fast target, which brings in the necessity of proofing the networks against attack. Lastly the security aspects are becoming more and more important. This paper addresses all these aspects and based on the current trends attempts to forecast the future tactical network.

2. COMMAND AND CONTROL

The armed forces carry out their role of defending the country by exercising their fire power. The scenario has now changed significantly, necessitating improved communication facilties. Modern weapon systems are faster, accurate and capable reaching deeper into enemy's territory. The battle commanders have less time to take decisions and react to the situation. Quicker decisions require precise information of the targets, troop movements, enemy's strength, own strength, terrain and metereological conditions. A C^4I system which helps in the above task has the role to sense, collate and compile, analyse, and disseminate the data to the field commanders to enable them to take decisions and issue orders for various formations.

These functions involve sensor processing to be done at sensor location and communicated along the hierarchial chain. The compilation, carried out either manually or using a computer, is presented to the decision making authorities. This is then analysed and relevant orders are disseminated down the chain of command and filtered information is communicated up

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the chain or command. All the information referred here are in the form of voice, data, text or images/maps/graphical representations. The future tactical communication networks should enable these functions in a real-time or near real-time. The following sections indicate the type of tactical communication system that will be offered in the future.

To enable the above functions the tactical communication network must provide the type of services as indicated in Table 1.

Table 1. Tactical communication network services

Service	Bit-rate
	16 kb/s (ADM)
	2.4 kb/s (LPC-future)
Digital fax	<64 kb/s
Interactive data	9.8 kb/s
Query-response	9.6 kb/s
Database update	<16 kb/s
Bulk sensor data	<100 kb/s
Data processing access	<200 kb/s
Freeze frame video	<128 kb/s
Slow scan TV	<128 kb/s

3. INTEGRATED SERVICES NETWORK

Tactical networks were hitherto predominantly voice with a provision for point-to-point transmission of data. Though systems like Joint Tactical Information Distribution System (JTIDS) were existing, they were either independent or overlay networks and were not really designed to provide integrated service of the type given in Table 1. The integrated services require uncommitted 'bearer' channel on which one can send digital voice, data, digital facsimile or image in a synchronous or an asynchronous mode. The information can be either circuit or packet switched. The bearer channel is selected on the basis of bandwidth of one digitised voice channel which is presently 16 kb/s in tactical networks using continuously variable slope delta (CVSD) modulation. This enable bandwidth conservation in radio system which is the main link equipment. The commercial system uses 64 kb/s for their B-channel as pulse code modulation (PCM) for voice.

The signalling for the tactical communication network is based on common channel signalling which can either follow the standard of the respective country, if any, the CCITT 7 scheme. In this, the signalling information is sent as massages on a 16 kb/s D-channel, using seven-layer SS 7 protocols. The spare capacity is used for packet switched data.

The requirement of integrated services demands that a subscriber in tactical network should have a (B+D) or more desirably a (2B+D), facility in conformity with standard Integrated Services Digital Network (ISDN) practices.

The switching systems of the tactical communication network, in future, will be a digital switch with digital line terminations (LT) at the exchange. The ISDN interface standard (S,T,U) will apply to the tactical networks except that in most of the cases the subscriber instrument will directly provide U interface, thus eliminating the need for network terminator (NT).

Future tactical communication network will be an ISDN, catering for terminal equipment like digital field telephone, data terminals, PCs, TV cameras, graphic terminal, etc. A representative diagram is shown in Fig. 1. An important future to be noted here is that the network is end-to-end digital in nature. It should also be noted that the network as such will shift from place to place with its constituent elements occupying different geographical as well as relative position given the number of nodes, terrain conditions, radio path loss, congestion factors, and fault status. The network has to be properly planned and maintained. An initial planning with the aid of an expert system with the geographical information system will enhance functionality of the network to provide uninterrupted service. A network management system as an integral part will be one of the most important elements of the future tactical communication networks. A network with these attributes will be able to transfer voice, data, images and map/map overlays, enabling command and control functions.

4. NETWORK TOPOLOGY

Figure 2 represents the preferred topology for a tactical network. The network will employ two-level switching, viz local and trunk switching. The topology, though regular in structure, has its nodes distributed at geographically varying distances from each other. The major elements of the network are the node switches, local switches, UHF/VHF radio relays, mobile access radio system, subscriber instruments and computers and computer terminals. Like commercial networks, the

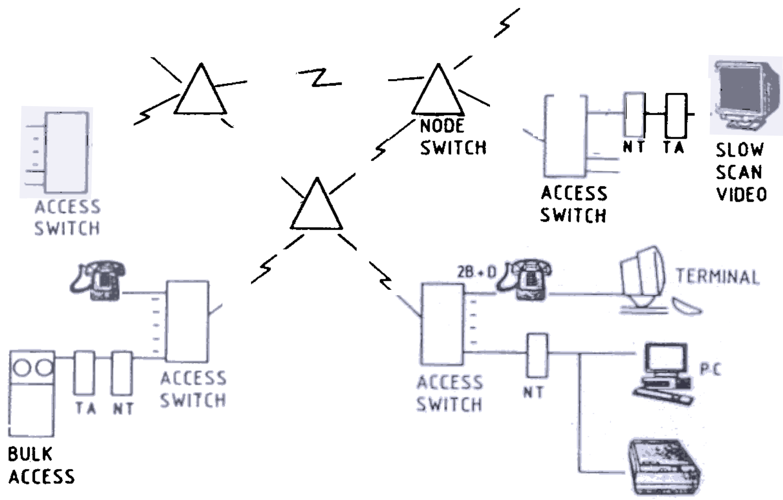

Figure Integrated services.

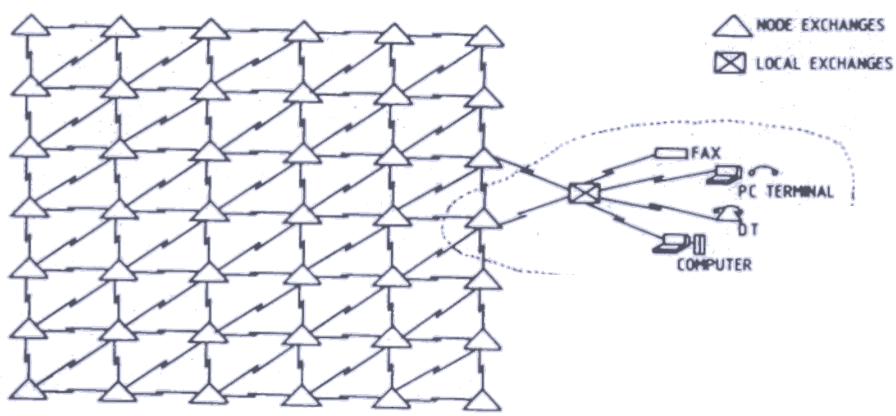

Figure 2. Mesh topology

calls tend to be limited to the subscribers' own domain activity. But unlike commercial systems only few subscribers will access the trunks to make calls up the echelon. The information gets filtered at each level to the required detail. A lateral information flow takes place to the adjacent formation mainly to gather intelligence and to ascertain own as well as enemy status. The traffic, which tends to be rough and erratic during the operations, is otherwise smooth. Since tactical communication system should cater to the war situation, the topology of the network should be such that it would be possible to communicate even in the face of such erratic traffic and destruction. The network of future will adapt itself dynamically to changing traffic patterns, destruction/failure of links/node equipment by use of techniques, such as adaptive routing.

4.1 Adaptive Distributed Routing

This routing strategy adapts itself dynamically to the changing conditions of the network; the routing decisions are taken at each node packet and traverse in a distributed fashion. At every node in the network, a routing table containing the path from this node to any destination node in the network is maintained. Every time there is a significant change in the network parameters as seen by a node; the node updates its table and also passes this information to its neighbours. This updated information seeps through the network and gets registered in the routing tables of all the nodes. The packets are routed by a node chosing a direction as indicated by the routing table, so that routing decisions are taken at each node till it reaches the destination. The network parameters which are monitored and used for changing the routing table could be delayed due to queue length, link capacity vis-a-vis congestion numbering of established logical channel on a link, and channel error rate, etc.

Adaptive distributed routing is particularly suitable for tactical communication environments where network connectivity itself is changing frequently, and the peak traffic conditions leading to congestion are common.

The future networks, designed to handle unpredictable traffic, will ensure reliable connections in the face of congestion by resorting to advanced routing strategies. The tactical networks will guarantee good quality connection for all its services over the network.

4.2 Digital Telephones

The digital telephones for tactical applications will draw significantly from the commercial system except that the coding will be CVSD instead of PCM. Other coding schemes viz, RELP and CELP are likely candidates for the future since they offer lower bit rates (4.8 kb/s). Their introduction, however, will depend on the possible improvements in quality and speaker recognition with improved DSP techniques. RELP is already being used in mobile telephone systems. Out of two candidates for full duplex two-wire transmission, the echo cancellation technique is likely to score over the time compression multiplexing because of improved DSP techniques and better noise performance.

4.3 Encryption in Digital Telephones

The most important feature of the future network is the fact that the system is end-to-end digital. More electronics will be packed in the user terminal providing facilities for data, voice, text and interface for image transmission. Encryption per subscriber is easily incorporated. More details are discussed under network security.

5. TACTICAL REQUIREMENTS VIS-A-VIS STANDARDS

The main difference between a commercial system and a tactical system is the media and its behaviour. In the commercial system the transmission environments are controlled, whereas the same is error prone in tactical environments. Many of the standards though applicable and also desirable to the followed, the error correction requires more rugged scheme. Future tactical networks will adopt the standards, with suitable changes for error performance. CCITT standards lend themselves elegantly for this role because of interfacibility with commercial systems and strategic as well as public telephone/data networks.

The CCITT standards are comprehensive and cover areas like digital subcriber signalling, common channel signalling SS 7, link access protocols, higher level functions like transaction capability application part (TCAP), operations and management application part (OMAP) enabling remote database accesses, and network management (Recs. M.20, M.30, M.36, Q-771-775, Q-795). These are based on ISO-OSI protocols. Other facilities like E-mail (which will be a fact of life in future) can be easily added (X.400).

6. IMAGES, MAPS AND OTHER GRAPHIC INFORMATION TRANSFERS

Transmission of still/moving images, maps and its overlay information, and text (authentic signed documents conveying orders) will be playing major role in future combat environments. Though still pictures, after image compression (using JPEG standards) can be transmitted over 2B channels (16 kb/s each) given sufficient time (1-2 s), the moving pictures at 30 frames/s will require as many as 8D channels for transmission of glossy frames (using MPEG or CCITT H-261 standards) of acceptable level. This facility will be required for unmanned intelligence missions. Since such facilities are required in important command centres only, an 8B +D facility can be provided. The same channel can be made use of for bulk transfer of data between computers. The text transmission will follow group 3 or group 4 fax standards which can be put on a 2B+D line. The above facilities will be widely in C^4 I systems as the graphic/textual data transfers cater for Map overlays, unthenticated intelligence reports will be the main role of C^4I networks.

7. MOBILE SUBSCRIBER ACCESS

High level commanders on the move most have jam resistant secure voice/data communication capability, which will be provided by a mobile radio network with ECCM features. Multiple access spread-spectrum alternatives such as, direct sequence frequency division multiple access (DSFDMA). Direct sequence time division multiple access (DSTDMA) or a hybrid direct sequence frequency hopping time division multiple access (DSFHTDMA) would be very attractive but all these options require a bandwidth of 30 MHz or more, which cannot be allotted to the network in VHF band. The best alternative therefore appears to be a network based on frequency hopped multiple access (FHMA).

A FHMA technique-based mobile networks could provide a 20 dB processing gain using a total of 12 MHz radio bandwidth. Six simultaneous voice calls and several data calls from a group of 20 mobile users would be possible. In addition to the six FH traffic channels, a dedicated FHDMA-based control channel for signalling messages, crypto/FH key distribution and data subscribers is visualised. Voice operated switching 'on' of carriers and a global key generation strategy could keep self interference of the system within acceptable limits. The radio network could either directly access a node switch or have a access through a subscriber group multiplexer to a local switch.

8. DIGITAL LINKS

Local switch-to-node link capacities of 256/512/1024 kb/s matching with the local switch configuration and node-to-node link capacities of 1024/2048 kb/s would be required. There are a number of options for digital links between nodes and between nodes and local switches. Some of the more important of these are discussed below.

8.1 LOS Radio

New light weight low power digital radio relay in the 7/8 GHz and 14/15 GHz band capable of supporting transmission upto 2.0 Mb/s is visualised. A bandwidth efficient modem using QPSK/QPRS modulation and a spread-spectrum modem using hybrid DS/FH techniques will meet requirements of normal operation and operation under jamming. Upto 28 dB spread-spectrum processing gain could be achieved using a 300 MHz bandwidth. Existing band below 1.5 GHz could also be used for new digital radio but with a reduced spread-spectrum processing gain of the order of 16 dB.

8.2 Digital Troposcatter Links

Tropo links will continue to be attractive for long terrestrial links when intermediate relays cannot be used. New digital modem techniques such as digital adaptive receivers are quite attractive and for a 4/5 GHz system using quad space/frequency diversity ranges of upto 300 km with better than 99 per cent availability could be achieved at a trasmitter power of 2 kW. More sophisticated adaptive tropo system now under development could also be used if proved successful.

8.3 Digital Satellite Links

Although both TDMA and FDMA approaches are available for multiplexed digital links between nodes, TDMA has the advantages of higher bandwidth utilisation and flexibility in terms of dynamic changes in link capacity and connectivity between nodes. Direct sequence spread-spectrum TDMA would be preferred but may not be feasible because of large bandwidth requirements. Using TDMA, half satellite bandwidth of 18 MHz would be sufficient to provide about 700 two-way 16 kb/s digital trunks between 24 nodes which could be doubled by using digital TASI. TDMA burst will also include 2.4 kb/s low bit rate speech and data packets.

8.4 Fibre Optic Links

Light weight, smaller size, large bandwidth, freedom from interception and the potential for long repeaterless span are the major advantages gained by the use of optical fibres for military communications. Digital optical fibres links are attractive for both short haul applications, say between nodal switches and the radio relay equipment, and for long haul links between nodal switches. In the present st... of-art repeaterless span of 30 km could be obtained usin 50 μm GI optical fibre and operating at 1300 nm with laser sources and *Ge* APD detectors.

9. NETWORK SECURITY

The first lavel of encryption will be at the digital subscriber set for voice and at the packet level for data. Digital link encryption devices would provide the second level of secrecy. The terminal encryption unit could be either a plug-in unit or an add—on unit to the subscriber set. The link encryption unit will be a discrete one co-located with the local/nodal switch.

9.1 Key Distribution

The need for the periodic updating of keys in crypto systems is well known. Public key encryption (PKE) which uses the concept of a private key and public key corresponding to each user to recent innovation and is ideally suited for key distribution unit (KDU) associated with say, the local switch at the calling end can distribute a randomly generated 'session' key to both calling and called party. Alternately, a calling and called party could directly agree on a 'session' key after exchanging each others public key followed by randomly generated key encrypted using the public key. The former approach requires a KDU at the each of the local switches which stores public keys of all its local subscribers. In either of the alternatives, the crypto unit at the subscriber sets will be required to have a powerful computation capability so that setting up of 'session' key takes no more than a few seconds.

Keys of links secrecy devices wili have to be updated periodically. This could be achieved by direct exchange of information between link secrecy devices or by distribution of necessary data from a centralised key distribution centre (KDC). In either case, The PKE technique will be used as a 'master' key.

In view of the large control over heads, it is difficult to provide to new key for each data packet. One possible solution is to have a global key for the packet network which is updated very frequently by the KDC.

10. NETWORK RELIABILITY

The network reliability is the function of the individual hardware and software, link reliability. The reliability of hardware and software is taken care of at the design stage using appropriate redundancy techniques like the standby (duplex, triplex), modular, and hybrid redundancy.

The software reliability is implemented using rollback redundancy method. This also ensures software quality at the time of design. The link reliability is ensured at the time of network planning to avoid working at the radio relay at the very limits of its range, and offer acceptable noise performance. The hardware systems of the future tactical networks will be of 'very high availabilty' grade offering 99.999 per cent. This is made possible with the availability of highly reliable VLSIs incorporating testability features and inbuilt redundancy with majority voting.

11. SURVIVABILITY

A high level of survivability against physical destruction, equipment failures, jamming and wide fluctuations in traffic is an essential feature of tactical network. This is achieved by the incorporation of many of the features mentioned earlier. However, fluctuations in traffic and the resulting congestion require special routing techniques. Future systems will be distributed adaptive routing techniques as against presently used deterministic and flooding techniques. The tactical networks will also incorporate redundant links through different media for meeting survivability criteria.

12. REAL-TIME ASPECTS

The tactical network of the future will have very fast reponse time for queries, Apart from the use of fast processing units, the use of real-time operating system, relational or object-oriented database management systems and icon driven queries, modern compression techniques to enable a map or a picture to be represented by smaller volume of data will futher reduce communication overheads by compacting the volume of transmitted information. As these techniques take care of the real-time issues at file transfer, better design of CPUs further reduce interrupt latency time which are essential for deeply embedded real-time applications.

13. RELEVANCE OF B-ISDN AND CELLULAR RADIOS

Broadband ISDN is based on asynchronous transmission of cell of fixed length of 53 bytes. They are slated for data rates of 45 Mb/s up and aims at real-time transmission of moving pictures in addition to speech and data. It also assumes the availability of transmission media with corresponding ban width. This will be either a microwave or fibre optic link. Tactical networks themselves being mobile, the use of microwave link does not lend itself elegantly because of short beams requiring precise adjustments. The fibre optic link also requires frequent relaying as the formation moves. Fibre optic links are otherwise an attractive alternative for local switch-to-node and node-to-node links.

The millimeter waves with the broad antenna beams may be candidates for this role in the future. The cellular radio requires a stationary base station since a mobile base station will involve complex frequency management. This poses difficulties, hence it requires further studies. The impetus that is given to the personalised communication network (PCN), which is user-oriented rather than terminal-oriented, may see this system into the tactical scenario in the next century.

14. LOCAL AREA NETWORK

The computers and intelligent terminals will be the building blocks of a C^4I system. As these are going to be used in large numbers, their intercommunication with a small area without availing B+D or 2B+D channels of tactical network may become an overwhelming necessity. This will be more in evidance as we see more and more packet terminals and computers becoming a fact of life. A LAN or more appropriately a wireless LAN with a gateway to tactical network will be an exciting possibility of the next decade. In fact this can be a part of a PCN of the future.

15. NETWORK MANAGEMENT SYSTEM

The future tactical systems will be complex requiring varied types of terminal equipment, switching systems, digital radio links, secure systems and correspondingly complex software embedded in each. Such a network requires careful planning, maintenance, corrective measures in the face of congestion and ability to reconfigure in the event of the destruction. This requires an effective network management systems (NMS). The NMS thus becomes a near real-time Distributed Data Base System Network to function as : (a) An expert system for planning the network based on a given terrain condition connectivity using a Geographical Information System (GIS) software, (b) a resources management system, (c) a network monitoring system, (d) a network maintenance advisory system, and (e) a reconfinguration management system.

The CCITT recommendations M.20, M.30, M.36, Q-771-775 and Q-795 covers these aspects extensively and this will be the guiding factor to this all important NMS of the future tactical networks.

16. TRENDS

The emergence of VLSIs like superpipelined and superscalar processor (RISC/CISES) and DSP chips can be networked to form multiprocessor which will enable the following :

(a) Subscriber terminal more versatile with inbuilt data terminal, encryption with very low bit-rate speech coding, thus providing the capability to combine speech, data, images in a narrow spectrum. A forward observer can interface, with night vision binocular/telescope, the CCD camera and his terminal, providing better intelligence.

(b) CPUs at the switching nodes may process and switch images in real-time making vedio conferences with documents (text or graphs) for perusal by the participants bringing multimedia into the domain of tactical networks.

(c) The emerging field of photonic switching will keep pace with the required speed of switching.

(d) Powerful encryption systems for the subscribers as well as links (also offering better facilitiy of cracking the enemies code)

(e) Incorporation of better error correction feature to be built-in.

(f) Incorporation of advanced features in the link radio equipment, viz, ECCM, error correction.

(g) Implementation of bandwidth efficient modulation like Gaussion mean shift keying (GMSK), trellis coding etc., for mobile radio systems implementation of high availability local and node switches with fault tolerant features.

(h) Realisation of better query/response time for database accesses.

(i) Fast switching required for B-ISDN tailored for tactical applications.

(j) Packetised speech and speaker identification.

17. CONCLUSION

The tactical networks of the future will be intelligence networks on which any information can be transferred. By virtue of this, the network will have all the multimedia features enabling the field commanders to see what a forward observor or RPV sees, to get an expert opinion for decision support, send authenticated text as orders and as usual hold voice calls with a very high degree of security.

The trends in tactical communication indicate that the system must provide multimedia services (including vedio) which will necessitate the avilability of more bandwidth. The technology should, however, aim at conserving the bandwidth with better modulation technique, efficient data transfer protocols, and better data/image compression technique. The development in speech/speaker recognition and natural language understanding will increase the user friendliness of the network by providing better graphical user interface (GUI). The tactical network of the future will be complex in several aspects such as mobility, multimedia services, advanced techniques embedded in the equipment. As such, these types of networks should be modelled and simulated in order to analyse the adequacy of the networks to meet the demands of traffic and survivability. This should be taken up concurrently so that the system is kept updated. Development in the areas of photonic switching coding techniques are to be watched so that they can be promptly absorbed.