TACTICAL NETWORKS QUEUING THROUGH EVER-CHANGING COMMUNICATION SCENARIOS

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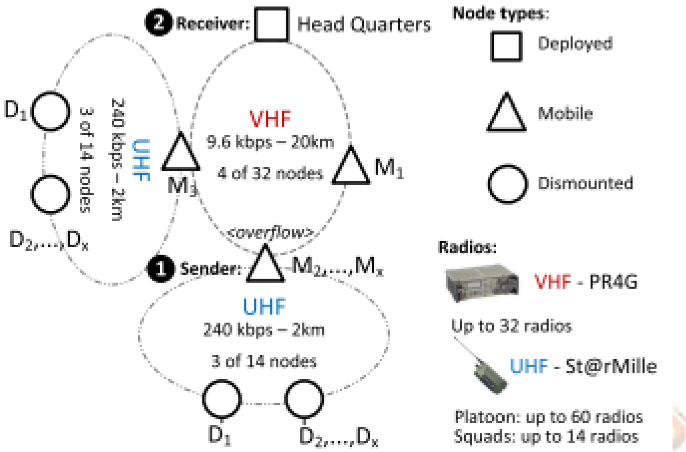
Abstract - In This paper introduces a hierarchy of queues complementing each other to handle ever-changing communication scenarios in tactical networks. The first queue stores the QoS-constrained messages from command and control systems. These messages are fragmented into IP packets, which are stored in a queue of packets (second) to be sent to the radio buffer (third), which is a queue with limited space therefore, open to overflow. We start with the hypothesis that these three queues can handle ever-changing user(s) data flows (problem A) through ever-changing network conditions (problem B) using cross-layer information exchange, such as buffer occupancy, data rate, queue size and latency (problem A|B). We introduce two stochastic models to create sequences of QoS-constrained messages (A) and to create ever-changing network conditions (B). In sequence, we sketch a control loop to shape A to B to test our hypothesis using model A|B, which defines enforcement points at the incoming/outgoing chains of the system together with a control plane. Then, we discuss experimental results in a network with VHF radios using data flows that overflows the radio buffer over ever-changing data rate patterns. We discuss quantitative results showing the performance and limitations of our solutions for problems A, B, and A|B.

Index Terms: Ever-changing communication scenarios, tactical networks, hierarchical queuing, robust control loop

Introduction :

Recently, TACTICAL networks are heterogeneous radio networks used by the military to connect mobile nodes in the battlefield [1]. These nodes are supporting users collaborating to accomplish a mission using a set of Command and Control (C2) services, such as friendly/hostile force tracking, medical evacuation, chat and so on. Given the wide range of military missions (e.g., combat, reconnaissance and disaster response), the users will combine C2 services in different ways to achieve their objectives. Remember that these services may have different Quality of Service (QoS) requirements like priority, reliability and time of expire. The challenge is to meet the QoS requirements over radio links exposed to several sources of randomness. For example, the source of randomness in tactical networks are the node/network mobility, physical obstacles on the way, physical attacks from hostile forces, the presence of an active adversary jamming the spectrum and so on. The combination of these random effects will influence the patterns of change in both user-generated data flows and network conditions observed during simulations or field experiments. Therefore, the distributions of change are unknown until the experiment is executed. We are using stochastic models to define the distributions of change before the experiment is executed. This investigation assumes that the communication scenarios in tactical networks are composed by at least two parts changing independently, the user data flows and the network conditions, defined here as problem A and B, respectively. Given the number of combinations between possible states of A and B, we call it ever-changing communication Thus, the challenge is to design tactical systems that can deliver the user data flows, given certain network conditions. We call it problem A|B reusing the conditional probability notation [2]. These three problems are partially addressed in the literature reporting simulations and field experiments in tactical networks. For example, it is common to find studies using non-stochastic user-generated data flows with few types of messages sent to the network within an uniform time window (problem A). Thus, we defined the stochastic model A to combine different types of messages creating sequences of messages with a known distribution of change that can be reproduced for quantitative verification or quantitative comparison. Moreover, the changes in the network conditions are defined by choosing the mobility model, communication technology, propagation model and so on. This is an indirect way of defining the degree of change of the network conditions, which is difficult to reproduce for quantitative comparisons (problem B). We introduced a direct approach using model B to create sequences of network states to configure the radios during run time. Our model uses conditional probabilities to define in precise terms the distribution of change to study the performance bounds of tactical systems.



II. LITERATURE SURVEY

This paper describes a hierarchical queuing mechanism designed to monitor and [1]control radio buffers while delivering web services in tactical networks. Our solution was motivated by the restrictions imposed by VHF radios, which have large coverage (~20 km) but very low data rate (e.g. up to 9.6 kbps). Therefore we implemented two queues, one for messages (Qm) and another for IP packets (Qp), shaping the user-generated data traffic to avoid buffer overflow. The queues complement each other, behaving like control points in a feedback loop. Both control points use the current radio buffer occupancy to decide when to dequeue messages and IP packets. We studied the performance of a prototype in a testbed using real military radios with focus on two variations of our control mechanism (reactive/proactive). The quantitative analysis shows our queuing mechanism successfully avoiding buffer overflow under challenging network conditions. Describe [2] our first experiments in applying SOA Web services to mobile nodes that are connected using Wireless Broadband Mobile Networks (WBMN) in the tactical domain. The experiments involved components provided by various nations, including radio hardware equipment, the Publish/Subscribe messaging service and NATO Friendly Force. **[3]** The Anglova scenario is designed to support experimentation with tactical networking environments and provides node mobility and network connectivity for a realistic battalion-sized military operation consisting of three vignettes, including the deployment of armored vehicles, surveillance of the maritime domain and an urban operation with a naval component. In this paper a comparison has been presented between tactical wireless networks and commercial wireless network. The implications of cognitive radio technology have also been explored for upcoming tactical wireless networks, considering benefits, technical aspects and security. Many organizations and nations are planning to apply Cognitive Radio Network technology (CRNT) [4] to tactical wireless communication networks. This study will also describe that why tactical wireless networks have been lag behind than commercial wireless networks in technologyTactical networks may deal with unexpected conditions in both kinetic (an adversary) and digital (cyberwarfare) [5] domains. Experiments in the literature lack the element of surprise (randomness) and the dynamic nature of such environments in both users' behavior (e.g. varying QoS-constrained dataflows) and network conditions (e.g. random variations among network states). Therefore, in this paper we propose a model to create ever-changing communication scenarios with dynamic users' behavior (problem A) Using Commercial off-the-shelf (COTS) software over networks that are Disconnected, Intermittent and Limited (DIL)[6] may not offer acceptable performance. Frequent network interruptions for both shorter and longer periods, as well as long delays, low data and high packet error rates characterize DIL networks. In this paper, we designed and implemented a prototype proxy to improve the performance of Web services in DIL environments.

III. EXISTING METHOD

SENSE's predictor is based on a combination of the Fixed- Share Experts algorithm and EWMA. Therefore, as background information, in this section we review EWMA and the Fixed-Share Experts algorithms in details.

EWMA based predictors, calculate an exponentially weighted mean of the previous data.

$$x_t = \alpha * y_{t-1} + (1 - \alpha) * x_{t-1} \qquad (1)$$

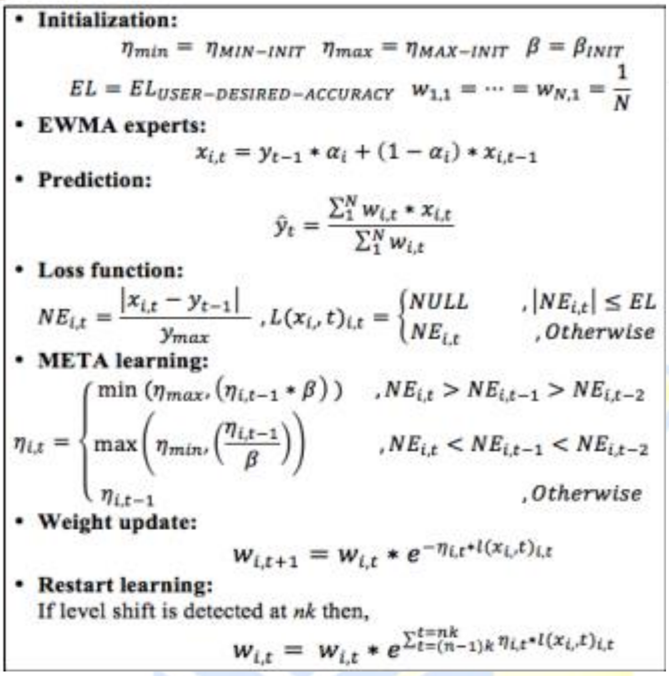
Fixed-Share Experts Algorithm The Fixed-Share Experts algorithm is a member of the multiplicative weight algorithmic family that has shown to yield performance improvements in a variety of on-line problems

$$\hat{y}_{t+1} = \frac{\sum_{i=1}^{N} x_{i,t} * w_{i,t} * \exp\{-\eta * \sum_{i=1}^{N} L_{i,t}(x_i, y_t)\}}{\sum_{i=1}^{N} w_{i,t} * \exp\{-\eta * \sum_{i=1}^{N} L_{i,t}(x_i, y_t)\}} = \sum_{i=1}^{N} \alpha_{i,t} * x_{i,t}$$

$$\text{Where } \alpha_{i,t} = \frac{w_{i,t} * \exp\{-\eta * \sum_{i=1}^{N} L_{i,t}(x_i, y_t)\}}{\sum_{i=1}^{N} w_{i,t} * \exp\{-\eta * \sum_{i=1}^{N} L_{i,t}(x_i, y_t)\}} \qquad (2)$$

SENSE

This section provides a detailed description of our online estimator, SENSE, which employs a combination of Fixed-Share Experts with EWMA. More specifically, SENSE is a modified version of the Fixed-Share Experts estimator, where, instead of fixed valued experts, EWMA filters are employed as experts.



- **Initialization:**

$$\eta_{min} = \eta_{MIN-INIT} \quad \eta_{max} = \eta_{MAX-INIT} \quad \beta = \beta_{INIT}$$

$$EL = EL_{USER-DESIRED-ACCURACY} \quad w_{1,1} = \cdots = w_{N,1} = \frac{1}{N}$$

- **EWMA experts:**

$$x_{i,t} = y_{t-1} * \alpha_i + (1 - \alpha_i) * x_{i,t-1}$$

- **Prediction:**

$$\hat{y}_t = \frac{\sum_1^N w_{i,t} * x_{i,t}}{\sum_1^N w_{i,t}}$$

- **Loss function:**

$$NE_{i,t} = \frac{|x_{i,t} - y_{t-1}|}{y_{max}}, L(x_i, t)_{i,t} = \begin{cases} NULL & , |NE_{i,t}| \le EL \\ NE_{i,t} & , Otherwise \end{cases}$$

- **META learning:**

$$\eta_{i,t} = \begin{cases} \min(\eta_{max}, (\eta_{i,t-1} * \beta)) & , NE_{i,t} > NE_{i,t-1} > NE_{i,t-2} \\ \max\left(\eta_{min}, \left(\frac{\eta_{i,t-1}}{\beta}\right)\right) & , NE_{i,t} < NE_{i,t-1} < NE_{i,t-2} \\ \eta_{i,t-1} & , Otherwise \end{cases}$$

- **Weight update:**

$$w_{i,t+1} = w_{i,t} * e^{-\eta_{i,t} * l(x_i, t)_{i,t}}$$

- **Restart learning:**

If level shift is detected at *nk* then,

$$w_{i,t} = w_{i,t} * e^{\sum_{t=(n-1)k}^{t=nk} \eta_{i,t} * l(x_i, t)_{i,t}}$$

IV PROPOSED METHOD

Ever-Changing Data Flows

Let us assume that a set of command and control services are available to the user(s) through mobile nodes in a tactical network. Each service has its own set of QoS-requirements, predefined by experts or computed during run time, which are included in the message header. For example, Table 2 lists five exemplary services together with their frequency, priority, reliability (yes or no) and Time of Expire (ToE). Priority is a number representing four different types from 0 (highest) to 3 (lowest), namely flash 0, immediate 1, priority 2 and routine 3. Reliability means that the receiver must acknowledge edge the sender when the message is successfully received. If the message is lost or partially received, the system must re-send the entire message or the lost packets. Notice that we also included the "no service call" s0 to represent the state where no message is sent to the tactical network. Given a mission or operation, the users will combine services with different QoS-requirements to achieve their objective(s). The frequency of messages sent to the network depends on the action in the battlefield therefore.

$$X_0 \begin{array}{c} \begin{array}{ccccc} s_0 & s_1 & s_2 & s_3 & s_4 \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \end{pmatrix} \end{array} \quad A_1 \begin{array}{c|ccccc} & s_0 & s_1 & s_2 & s_3 & s_4 \\ \hline s_0 & .40 & .20 & .30 & .05 & .05 \\ s_1 & .40 & .20 & .30 & .05 & .05 \\ s_2 & .40 & .20 & .30 & .05 & .05 \\ s_3 & .40 & .20 & .30 & .05 & .05 \\ s_4 & .40 & .20 & .30 & .05 & .05 \end{array}$$

$$A_2 \begin{array}{c|ccccc} & s_0 & s_1 & s_2 & s_3 & s_4 \\ \hline s_0 & .20 & .20 & .20 & .20 & .20 \\ s_1 & .20 & .20 & .20 & .20 & .20 \\ s_2 & .20 & .20 & .20 & .20 & .20 \\ s_3 & .20 & .20 & .20 & .20 & .20 \\ s_4 & .20 & .20 & .20 & .20 & .20 \end{array} \quad A_3 \begin{array}{c|ccccc} & s_0 & s_1 & s_2 & s_3 & s_4 \\ \hline s_0 & 1 & 0 & 0 & 0 & 0 \\ s_1 & 0 & .10 & .20 & .30 & .40 \\ s_2 & 0 & .10 & .20 & .30 & .40 \\ s_3 & 0 & .10 & .20 & .30 & .40 \\ s_4 & 0 & .10 & .40 & .49 & .01 \end{array} \qquad (1)$$

Ever-Changing Network Conditions:

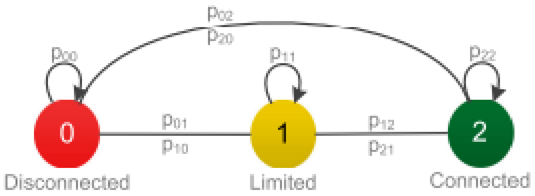


Fig.4.0: The three network states: 0, 1 and 2.

Modeling the Ever-Changing Network States: We noticed that our VHF radios have a SNMP interface to change the radio modulation supporting five data rates, namely 0.6, 1.2, 2.4, 4.8 and 9.6 kbps. Thus, we developed an algorithm to change the radio data rate in run time following a given pattern defined by our model B as follows. Let us use the five data rates supported by our radios as states of a Markov chain along with a state for disconnection, as illustrated in Fig. 4. In this figure, state 0 is disconnected, state 1 represents the data rate .6 kbps, state 2 represents 1.2 kbps and so on until state 5 that represents 9.6 kbps, which is the highest nominal data rate supported by our radios. Notice that the edges of this state-machine are defined in general terms as pij showing all the possible state transitions among the six states in a complete graph.

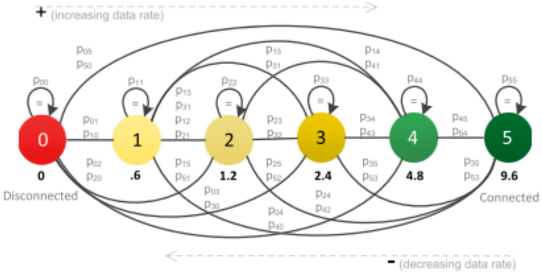


Fig.4: State machine with six states representing the radio's data rates including all possible transitions among the states.

IV.CONCLUSION

This investigation introduced two models to create everchanging communication scenarios in tactical networks including the element of chance (randomness) from both user data flows (model A) and network conditions (model B). In sequence, we sketched a third model A|B to define multi-layer control loops to handle the ever-changing conditions from model A given the current network conditions from model B. These three models were developed to test the performance bounds of tactical systems and are reproducible for quantitative comparisons. We verified our three models doing experiments in a VHF network using real military radios. Model A was used to create data flows with 500 kB of random payload known to overflow the radio buffer (four times the radio buffer) over the best network conditions (radios with wired antennas). Model B was used to create six different patterns of ever-changing network states with data rates varying from 0.6 to 9.6 kbps and also including link disconnections. We used model A|B to define a combination of a reactive/proactive control to shape the user-generated data flow coping with current network conditions. Our hierarchy of queues was continuously monitoring the radio buffer occupancy to pause the transmission when a pre-defined threshold was crossed (reactive). At the same time, it proactively inserted an interval between IP packets which was computed using the link data rate (compiled by the routing protocol), buffer occupancy and latency. Thus, the feasibility of our control mechanism has been validated in communication scenarios with both message types and link data rates changing independently

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