THEORY OF RESILIENCE OF MODERN LARGE COMMUNICATION NETWORKS TO INTENTIONAL EMI

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Abstract

This paper deals with quasi-revolutionary changes in the theoretical and mathematical way survivability of large complex communication networks are evaluated. One might say that serious interest in survivability communications began in the Cold War. Before strategic communications was recognized as a vital and certainly essential part of Cold War military strategy the only really big communication networks were those run by the telephone companies. Here the buzz word was network reliability instead of survivability. Switching through redundant paths almost always solved the problem. Strategic Cold War networks were relatively simple, often involving long sequences of electromagnetic-hardened nodes with limited redundancy. A theory of predicting the survivability of these networks for world wide time-varying EMP threats was developed by Kohlberg (System Design and Assessment Note No. 25, AFRL, 1982). This calculation was made possible by the essential fact that the location of the nodes was deterministic and in comparison to today's networks, relatively few in number. Calculating the probability of successful communication between any two nodes was straightforward.

Where are we today? "Modern" large communication networks such as the World Wide Web and the Internet have hundreds of thousands of nodes, while ad-hoc mobile networks may have hundreds to thousands of nodes. The locations of substantial numbers of these nodes change continuously with time as does the connectivity between any pair. We may not think so much about the survivability of these modern networks against the High Altitude Nuclear Threat (HEMP), but determining the resilience of these networks against a whole range of IEMI threats is essential. The analytical tools that are required to determine the resilience of modern networks against IEMI draw from the mathematical theory of random graphs and percolation theory. These theories show that the self-healing ability of a large network (its resilience) is its ability to support a network-spanning cluster. Being able to do this means to be able to essentially communicate over most of the physical size of the network with only a fraction of the nodes surviving! This concept is new to the subject of survivable communications.

We compute: (1) the size of a network-spanning cluster for a several types of IEMI threats; and (2) the size distribution of node clusters that are formed in network collapse. In addition, we discuss application of recently developed renormalization theory of Potrykus and Kohlberg (EMC-Zurich Singapore Conference 27 Feb—3 March'06) that leads to the creation of super-nodes that span the network in a manner consistent with the spatial variations of the IEMI threat. Interestingly, we find that some of the original theoretical algorithms of strategic communications can be used to support methods of calculating the resilience of large communications networks using renormalization theory.