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RTO TECHNICAL REPORT **TR-IST-030**

Information Management over Disadvantaged Grids

(Gestion des informations sur des maillages désavantagés)

Final Report of the RTO Information Systems Technology Panel Task Group IST-030/RTG-012.

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The Research and Technology Organisation (RTO) of NATO

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The total spectrum of R&T activities is covered by the following 7 bodies:

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These bodies are made up of national representatives as well as generally recognised 'world class' scientists. They also provide a communication link to military users and other NATO bodies. RTO's scientific and technological work is carried out by Technical Teams, created for specific activities and with a specific duration. Such Technical Teams can organise workshops, symposia, field trials, lecture series and training courses. An important function of these Technical Teams is to ensure the continuity of the expert networks.

RTO builds upon earlier co-operation in defence research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defence Research Group (DRG). AGARD and the DRG share common roots in that they were both established at the initiative of Dr Theodore von Kármán, a leading aerospace scientist, who early on recognised the importance of scientific support for the Allied Armed Forces. RTO is capitalising on these common roots in order to provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

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List of Acronyms

ACK	Acknowledgement
ARDS ADM	Artillery Regimental Data System Advanced Development Model
ARM	ATCCIS Replication Mechanism
ATCCIS	Army Tactical Command and Control Information System
BER	Bit-Error Rate
C2	Command and Control
C2IEDM	Command and Control Information Exchange Data Model
C2IS	Command and Control Information System
CCM	CORBA Component Model
CORBA	Common Object Request Broker Architecture
CSMA/CA	Collision Sense Multiple Access / Collision Avoidance
DACCIS	Danish Army Command and Control Information System
DBMS	Database management system
DC	District of Columbia
DCE	Distributed Computing Environment
DCOM	Distributed Component Object Model
DP	Data Provider
DR	Data Receiver
DRDC	Defence Research and Development Canada
FEC	Forward error correction
FGAN	Forschungsgesellschaft für Angewandte Naturwissenschaften
FhG	Fraunhofer-Gesellschaft
FKIE	Forschungsinstitut für Kommunikation, Informationsverarbeitung und Ergonomie
FOKUS	Fraunhofer Institut Offene Kommunikationssysteme
GPS	Global Positioning System
HQ	Headquarters
HTML	Hyper Text Markup Language
IEEE	Institute of Electrical and Electronics Engineers
IM	Information Management
IP	Internet Protocol
ISO	International Standards Organization
IST	Information Systems Technology
JMS	Java Message Service
JTRS	Joint Tactical Radio System
JXTA	Juxtapose
Kbps	Kilobits per second
LAN	Local Area Network
LBTB	Low Bandwidth Test Bed

LC2IEDM	Land Command and Control Information Exchange Data Model
LOS	Line of sight
MAC	Media Access Control
MANET	Mobile Ad Hoc Network
Mbps	Megabits per second
MIP	Multilateral Interoperability Programme
MTIR	MIP Tactical C2IS Interoperability Requirement
MTU	Maximum Transmission Unit
MVD	Majority Vote Detect
NATO	North Atlantic Treaty OrganiSation
NSA	National Security Agency
ODB	Operational Database
OFDM	Orthogonal Frequency Division Multiplexing
OGSA	Open Grid Services Architecture
OMG	Object Management Group
OSF	Open Software Foundation
OSI	Open Systems Interconnection
OWG	Operational Working Group
P2P	Peer to Peer
P2PS	Peer-to-Peer System
PDU	Protocol Data Unit
PfP	Partners for Peace
QoS	Quality of Service
RM	Replication mechanism
RMI	Remote Method Invocation
RTCORBA	Real-Time CORBA
RTG	Research Task Group
RTL	Replication Transport Layer
RTO	Research and Technology Organisation
SGML	Standard Generalized Markup Language
SINCGARS	Single Channel Ground and Airborne Radio System
SIP	Session Initiation Protocol
STN	Simulated Tactical Node
TCP	Transport Control Protocol
TD	Technology Demonstration
TNO	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek
UDP	User Datagram Protocol
UHF	Ultra High Frequency
VHF	Very High Frequency
WANODE	Wide Area Network for Operational Data Exchange
XML	Extensible Markup Language
zlib	Name of open-source lossless data compression algorithm

Acknowledgements

The Chairman would sincerely like to thank the members of IST-030/RTG-012 for their contributions to the Task Group's success. All Task Group members found themselves with serious demands on their time yet managed to find the time to advance Task Group objectives. The Chairman is very appreciative of their effort, perseverance and collaborative approach.

Thanks are also due to the home organizations of the Task Group members for providing the time and financial support necessary for the Task Group members to participate in six meetings and three associated workshops over four years. I am grateful to the organisations that hosted these meetings/workshops. They are, in order of hosting:

- RTO Headquarters, Neuilly-sur-Seine, France;
- Military Institute of Technology, Warsaw, Poland;
- DRDC Valcartier, Québec City, Canada;
- FGAN/FKIE, Wachtberg, Germany; and
- Naval Research Laboratory, Washington, DC, USA.

The Chairman would like to say a special word of thanks to Dr. J. Grosche and management at FGAN/FKIE who agreed to nominate Mr. Schmeing as a replacement for Dr. Fassbender when the latter left FGAN in 2002. Due to its small size, the Task Group could not have continued without this support. He is also very indebted to Herr Karlheinz Wagner and Frau Ute Spickermann of FGAN/FKIE and to BarbaraJo Cox and members of Ray Cole's Branch at NRL for their splendid logistic/administrative support of the second and third workshops. These workshops would not have happened without their timely and energetic support.

Of course, workshops are only as good as the people who attend them. Task Group members would join me in thanking the participants in the three informal Task Group workshops for their enthusiastic participation and excellent presentations. A special word of thanks is due to the Keynote Speakers at the first and third workshops, Dr. Sam Chamberlain of U.S. Army Research Laboratory and Professor Michael Pursley of Clemson University, whose strong presentations set the stage for two very successful events.

The Chairman would also like to thank the members of the IST Panel for their support and guidance, and members of the Panel Executive, particularly LCol Alain Gouay, LCol Patrick Prodhome, and Aysegul Apaydin for their generous support, particularly during the Task Group meetings at RTO Headquarters.

Finally, the Chairman would like to thank DRDC Valcartier, Mr. Jean-Claude St-Jacques and the other members of the 'High Capacity Tactical Communications Network' Technology Demonstration Project for contributing the simulation results presented in Chapter 7.

The Task Group hopes that its study has served to make a contribution to the understanding of a complex but under-appreciated problem of importance to all NATO forces, namely managing data flow over disadvantaged tactical wireless communications networks in a way that takes into account network state, battlefield state and operational importance of the data being transmitted.

Allan Gibb, Ph. D.
Chairman IST-030/RTG-012
February 2007

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Ad hoc network	Disadvantaged network	Mobile network
Adaptive middleware	Dynamic adaptation	Network analysis (management)
Combat net radio	Energy-constrained network	Protocols
Command and control	Information management	Radio communication
Computer networks	Information systems	Radio links
Cross-layering	Integrated systems	Requirements
Data links	Low bandwidth	Tactical communications
Data replication	Managed information exchange	Tactical radio
Data transmission	Military communication	Wireless network
Disadvantaged grid		

14. Abstract

This report summarizes a four-year study carried out by NATO RTG-012/IST-030 Research Task Group on the problem of "Information Management over Disadvantaged Grids". Such disadvantaged grids (e.g., tactical ad hoc military radio networks) are characterized by low bandwidth, variable throughput, unreliable connectivity, and energy constraints imposed by the wireless communications grid that links the nodes. The scope of this study was limited to land-based digital data exchange below brigade level where all nodes are mobile and the exchange medium is combat net radio. Managed information exchange in this communications environment was analyzed from three different perspectives within a system architecture: the application level, the middleware level and the network level. Due to the highly variable quality of the tactical communications channels and the unpredictable nature of the tactical battlefield, it was concluded that dynamic adaptation to rapid changes in either the communications or battlefield environment, without user intervention, was key to achieving optimum information exchange. This report identifies functional and performance objectives for the application, middleware and network levels that enable the levels to cooperate to detect and adapt to those changing environments in a way that will enhance delivery of data of highest operational importance.

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