STANAG 5066
Profile for High-Frequency Data Communications:

ROADMAP / STATUS

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STANAG 5066 Edition 1- Scope

- **Main body provides overview of the structure of the P**
- **List of Annexes**
  - A: Subnetwork Interfa
  - B: Channel A
  - C: D

Current Status: Ratified, Promulgated, Deployed

(NATO BRASS, BFEM66, USAF SCOPE COMMAND)

(Mandatory)
(info only)
ons (info only)
ata Rates above 2400 Bit/s (info only)
entation Guide and Notes (info only)
Messages and Procedures for Frequency Change (info only)

STANAG 5066 Edition 2
(*formerly Edition 1 Amendment 1*) - Scope

Draft 6 Forwarded 26 Sept 2005 and ratified by 14+ nations; to be promulgated

- **Main body provides overview of t**
- **List of Anne**
  - A
  - (Mandatory)
  - (Mandatory)
  - ub-layer an
  - ent (Mandatory)
  - mote Control Interface (info only)
  - etwork Client Definitions (Mandatory)
  - G: Waveforms for Data Rates above 2400 Bit/s (info only)
  - H: Implementation Guide and Notes (info only)
  - I: Messages and Procedures for Frequency Change (info only)

STANAG 5066 Edition 3 (*formerly Edition 2*) –Scope

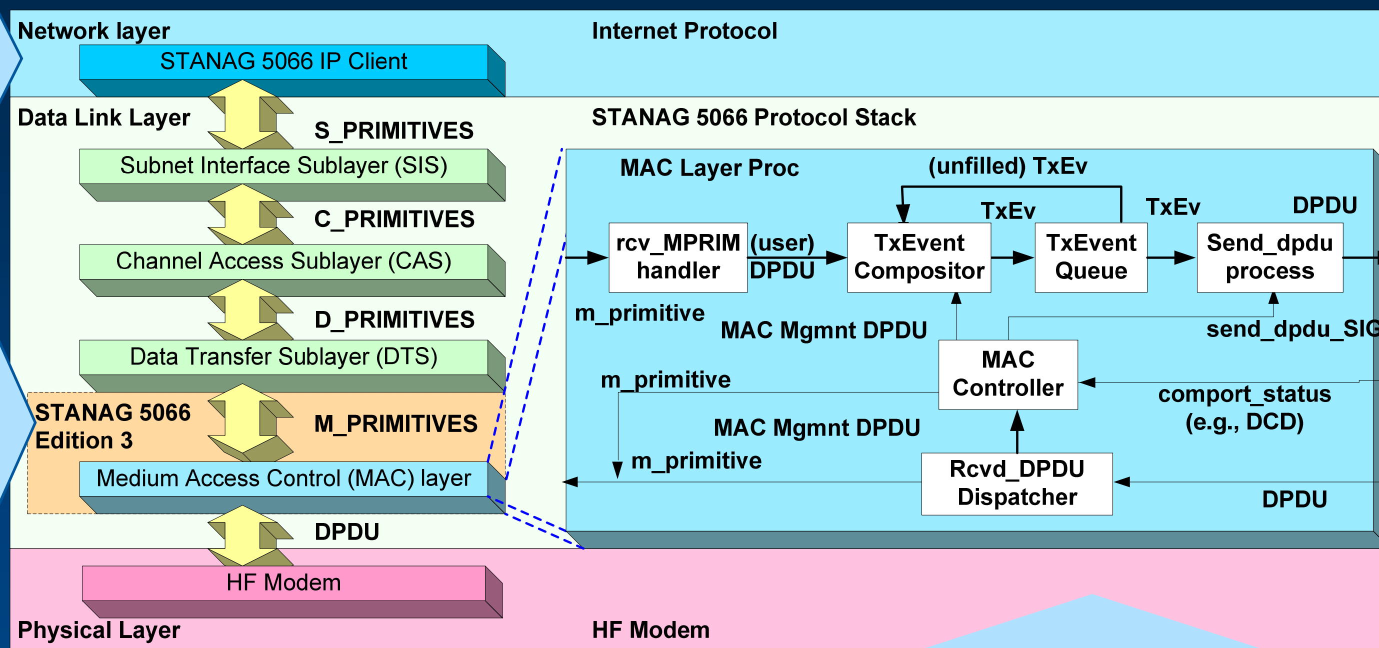
- **Main body provides overview of the structure of the Pro**
- **List of Annexes**
  - A: Subnetwork Interface Sub-layer
  - B: Channel Access Sub-layer
  - C: Data Transfer Sub-layer
  - D: Interface between Dat
    Communic
  - E: HF
  - (info only)
  - (info only)
  - (info only)
  - Protocols (info only)
  - Wireless-Token-Ring-Protocol (info only)
  - *reserved* *()*
  - N Addressing Guidance (info only)
  - O Integration with Internet Protocol (IP) Networks (info only)

Roadmap Endorsed by BLOS-COMMS AHWG Oct 2005 , work continuing …

Edition 3 (formerly Ed. 2) Overview

Annex F, N, O:
IP-over-HF Net-working, trunking & subnet relay

Annex J:
Overview of MAC-layer functionality
Relationship to other layers / annexes



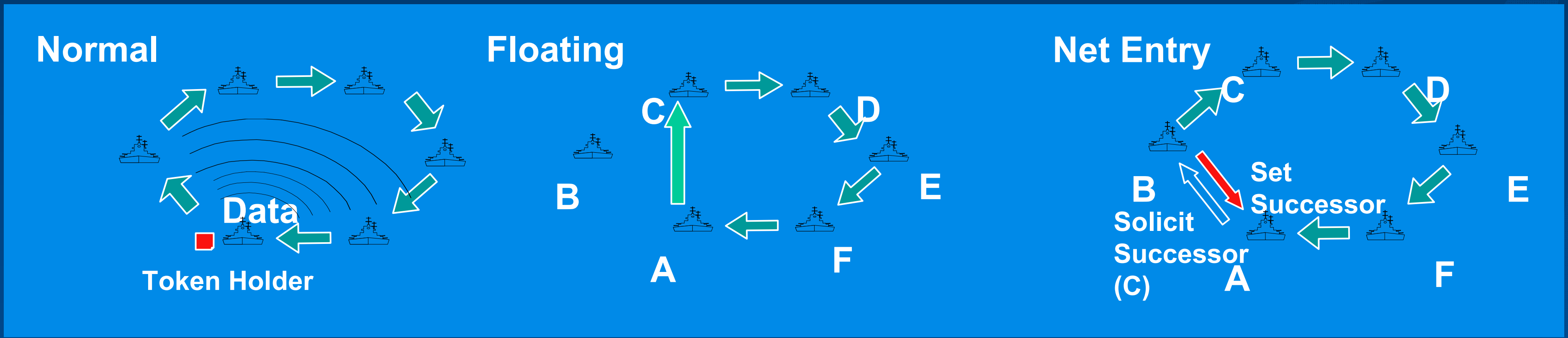
Annexes K, L, M: Tailored MAC-layer functionality for specific requirements:
- Annex K: Random-Access Protocols
- Annex L: HF Wireless Token Protocol (shown)
- Annex M: *reserved (e.g., for adaptive TDMA)*

Summary – Way Ahead

- Annex J Media Access Control Overview
  - Working Draft 2 reviewed by BLOSCOMMS, no reviewer objections, ready
- Annex K Random-Access Control Protocols
  - Working Draft 2 reviewed by BLOSCOMMS, no reviewer objections, ready
- Annex L High-Frequency Wireless-Token-Ring-Protocol
  - Incorporated/addressed comments by Thales
  - Demonstrated limited WTRP interoperability between USN and NC3A implementation
  - Working Draft 3 to be amended to incorporate USN developments in robust token-relay management; planned completion 3Q 2009
- Annex M *unused / reserved*
  - *Determine relevance – intended as placeholder for (adaptive) TDMA approaches based on S'5066*
- Annex N Addressing Issues
  - Working Draft 2 reviewed by BLOSCOMMS, no reviewer objections
- Annex O Integration with Internet Protocol (IP) Networks
  - Working Draft 1 incorporating current practice (e.g. USN/NC3A), to be coordinated with NATO WIRA and subnet relay requirements

Recent Efforts

- **Principal efforts in finalizing Annex L for Wireless Token Ring Protocol (WTRP), responding to:**
  - review/commentary on earlier draft (primarily by France/Thales, asking for more-capable token-relay support)
  - US Navy initiatives in implementing robust token-relay support sparse topologies (e.g., BLOS HF and UHF)



WTRP – A distributed, self-organizing, self-healing, asynchronous Media-Access-Control Protocol:

- ***net start, net entry, lost/missed tokens …***
- ***the ring defines the transmit-access cycle in the radio broadcast medium***

Token – Relay: the debate(1)

- **why and when is token-relay required (as opposed to relay of other traffic) :**
  - to relay the Right-to-Transmit when the successor is not reachable
  - in certain topologies (hub-and-spoke; linear)
    - these can occur as the ring grows in size and evolves even if the network does not require them in a later ring-configuration.
- **how to promote efficiency?**
  - restrict token-relay usage in the ring?
  - through optimistic joining?
  - ring-rethreading?

Token – Relay: the debate(2)

- **to what extent should token-relay be supported?**
  - the previous draft and implementations support one token-relay topology only, i.e., only on token relayer is allowed in the network;   _BUT_
  - USN has recently developed and tested a robust token-relay approach for sparse topologies where more than one relay may be required
- **Previous Annex L drafts adopted a conservative approach, previously implemented by US, that restricts the use of token-relay to limiting case of a three-node linear network**
- **What follows incorporates NC3A's present understanding of the current USN proposal and design for robust token-relay, as proposed at the BLOSCOMMS 2008/02 meeting.**

Principle of Extensibility : Example: HF-WTRP Token Message for Annex L

- **Extends S'5066 message catalog**
  - existing message type, new subtype
- **HF-WTRP token implemented as a Type-6 DPDU Extended EOW Message**
  - based on the UC Berkeley WTRP IERs
  - UCB-WTRP used wireless Ethernet MAC addresses (6 bytes)
  - this design uses 4-byte STANAG 5066 addresses, (w/ variable-length source and destination addresses)
- **WTRP token fields:**
  - FC - frame control
  - DA - destination address
  - SA - source address
  - RA - ring address (I.e., address of the node that instantiated the ring)
  - SN - sequence number
  - GSN - generation sequence number

Bit n.	7	6	5	4	3	2	1	0	Field encoding per S5066 Annex C, as amplified below:
	The two-byte message preamble is not shown;								
	0	1	1	0	1	1	1	1	DPDU_TYPE = 6, per S5066 Annex C;
	FC field (1) ∈ {Token, Solicit Successor, Set Successor, Set Predecessor, … }								**EOW_TYPE = 15** **EOW_DATA = HFTRP Frame-Control**
	END_OF_TRANSMISSION (EOT)								encoded per S5066 Annex C
	SIZE_OF_ADDRESS (m ∈ {1 … 7})			SIZE_OF_HEADER(2) (k = 28)					*m, k in bytes*, encoded per S5066 Annex C
m	SOURCE_AND_DESTINATION_ADDRESS								Field-length = m bytes; encoded perS5066 Annex C; **These fields correspond to the HFTRP DA and SA fields**
n		NOT_ USED_1			HAS_ BODY = 0	EXT MSG = 1	VALID MSG = 1	ACK	This is the extended form of the ID Mgmt EOW message; encoded per S5066 Annex C
n	MSB -	-- MANAGEMENT FRAME ID NUMBER --						- LSB	encoded per S5066 Annex C
n	Reserved for future use (2-bytes) (e.g., to-designate the length of any management-message payload)								**Potential HFTRP-required field (e.g., payload size)**
n	RA - RING_ADDRESS (4-bytes, in the address format of STANAG 5066 Annex A)								**HFTRP-required field (3)**
m	SEQ - SEQUENCE_ID (4-bytes, per the HFTRP requirement)								**HFTRP-required field**
m	GEN - GENERATION_SEQUENCE_ID (4-bytes, per the HFTRP requirement)								**HFTRP-required field**
m	NS - NEW_SUCCESSOR_ID (4-byte, context-dependent format, per the HFTRP requirement)								**HFTRP-required field**
m	NON - NUMBER OF NODES (2-bytes, per the HFTRP requirement)								**HFTRP-required field**
H_1	CRC_ON_HEADER							MSB	encoded per S5066 Annex C
H_2	LSB								

Legend: S'5066 Standard | Dual-use: S'5066 & WTRP | HFWTRP-unique

Token Structure for Multi-Hop Token-Relay

- **Explicit inclusion of transmit-order list (TOL) and Distance Matrix, intended to tackle the problems of multi-hop token-relay head on.**
- **Allows fast-response to topology changes**
- **Provides TOL optimization and recovery from sub-optimal TOL creation**

Byte/ Bit Num.	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*0*	*Field encoding per S5066 Annex C, as amplified below:*
	The two-byte message preamble is not shown;								
0 — (Header Length -1)	**DPDU Header** **Type-6 Management DPDU; Sub-Type 15** **(RTT Token),** **Number of Nodes = *NON* = N** **Body Length Field = 8 * (N + Ceil(N/2))**								**DPDU (Token) Header encoded per Annex L.3.2.1, Table L-2.**
	Ring Transmit-Order List (TOL)								EOW Payload Contents for Multi-Hop Token-Relay Algorithm Operation
	Node Distance Matrix (DM)								
CRC_B_1								**MSB**	Header on Body encoded per Annex C
CRC_B_2	**CRC_32 bits ON_PAYLOAD**								
CRC_B_3									
CRC_B_4	**LSB**								

Structure of Transmit-Order-List (TOL)

Provides

- **Global knowledge** of the Ring Transmit Cycle
- **Rapid dissemination** of TOL changes
- **Advertisement** of next solicitor-node
- **Support for Interface auto-configuration** through linkage of MAC-address to upper-layer protocol info (e.g., IPv4 address)

Byte/ Bit Num.	7	6	5	4	3	2	1	0	Field encoding per S5066 Annex C, as amplified below:
0	SOL = {0 | 1}	0	0	0	MSB				First Node-Address-Pair entry (in network-byte order)
1									
2	STANAG 5066 Node-Address 1								
3								LSB	
4	MSB								
5	IP-protocol usage (e.g., IPv4 Node-Address 1)								
6									
7								LSB	
8 (N-1) + 0	SOL = {0 | 1}	0	0	0	MSB				N-th Node-Address-Pair entry (in network-byte order)
8 (N-1) + 1									
8 (N-1) + 2	STANAG 5066 Node-Address N								
8 (N-1) + 3								LSB	
8 (N-1) + 4	MSB								
8 (N-1) + 5	IP-protocol usage (e.g., IPv4 Node-Address N)								
8 (N-1) + 6									
8 (N-1) + 7								LSB	

Distance Matrix Encoding (NON = Even)

- **Dense-packed matrix**
  - Variant packing for N even, and N odd
- **Size: Ceil ($N^2/2$)**
- **Dist(i,j) encodes the distance from n_i to n_j in 4 bits**

Byte/ Bit Num.	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*0*	Field encoding as amplified below:
0	*msb*	$\mathbf{dist_{0,0}}$		*lsb*	*msb*	$\mathbf{dist_{0,1}}$		*lsb*	First Row of the Distance Matrix
1	*msb*	$\mathbf{dist_{0,2}}$		*lsb*	*msb*	$\mathbf{dist_{0,3}}$		*lsb*	
	…	…		…	…	…		…	
Ceil(N/2)-1	*msb*	$\mathbf{dist_{0,(N-2)}}$		*lsb*	*msb*	$\mathbf{dist_{0,(N-1)}}$		*lsb*	
Ceil(N/2)	*msb*	$\mathbf{dist_{1,0}}$		*lsb*	*msb*	$\mathbf{dist_{1,1}}$		*lsb*	Second Row of the Distance Matrix
Ceil(N/2)+1	*msb*	$\mathbf{dist_{1,2}}$		*lsb*	*msb*	$\mathbf{dist_{1,3}}$		*lsb*	
*2*Ceil(N/2)-1*	*msb*	$\mathbf{dist_{1,(N-2)}}$		*lsb*	*msb*	$\mathbf{dist_{1,(N-1)}}$		*lsb*	
*(k-1)*Ceil(N/2)*	*msb*	$\mathbf{dist_{(k-1),0}}$		*lsb*	*msb*	$\mathbf{dist_{(k-1),1}}$		*lsb*	k-th Row of the Distance Matrix
*(k-1)*Ceil(N/2)+1*	*msb*	$\mathbf{dist_{(k-1),2}}$		*lsb*	*msb*	$\mathbf{dist_{(k-1),3}}$		*lsb*	
*(k)*Ceil(N/2)-1*	*msb*	$\mathbf{dist_{(k-1),(N-2)}}$		*lsb*	*msb*	$\mathbf{dist_{(k-1),(N-1)}}$		*lsb*	
*(N-1)*Ceil(N/2)*	*msb*	$\mathbf{dist_{(N-1),0}}$		*lsb*	*msb*	$\mathbf{dist_{(N-1),1}}$		*lsb*	Last Row of the Distance Matrix
*(N-1)*Ceil(N/2)+1*	*msb*	$\mathbf{dist_{(N-1),2}}$		*lsb*	*msb*	$\mathbf{dist_{(N-1),3}}$		*lsb*	
*N*Ceil(N/2)-1*	*msb*	$\mathbf{dist_{(N-1),(N-2)}}$		*lsb*	*msb*	$\mathbf{dist_{(N-1),(N-1)}}$		*lsb*	

N.B.: Ceil (x) is the smallest integer greater than or equal to x

Distance Matrix Encoding (NON = Odd)

- **Dense-packed matrix**
  - Variant packing for N even, and N odd
- **Size: Ceil ($N^2/2$)**
- **Dist(i,j) encodes the distance from n_i to n_j in 4 bits**

Byte/ Bit Num.	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*0*	Field encoding as amplified below:
0	*msb*	$\mathbf{dist_{0,0}}$		*lsb*	*msb*	$\mathbf{dist_{0,1}}$		*lsb*	First Row of the Distance Matrix
1	*msb*	$\mathbf{dist_{0,2}}$		*lsb*	*msb*	$\mathbf{dist_{0,3}}$		*lsb*	
	…	…		…	…	…		…	
Ceil(N/2)-1	*msb*	$\mathbf{dist_{0,(N-1)}}$		*lsb*	*msb*	$\mathbf{dist_{1,0}}$		*lsb*	Second Row of the Distance Matrix
Ceil(N/2)	*msb*	$\mathbf{dist_{1,1}}$		*lsb*	*msb*	$\mathbf{dist_{1,2}}$		*lsb*	
N - 1	*msb*	$\mathbf{dist_{1,(N-2)}}$		*lsb*	*msb*	$\mathbf{dist_{1,(N-1)}}$		*lsb*	
	msb	$\mathbf{dist_{(k-1),0}}$		*lsb*	*msb*	$\mathbf{dist_{(k-1),1}}$		*lsb*	k-th Row of the Distance Matrix
	msb	$\mathbf{dist_{(k-1),2}}$		*lsb*	*msb*	$\mathbf{dist_{(k-1),3}}$		*lsb*	
	msb	$\mathbf{dist_{(k-1),(N-1)}}$		*lsb*	*msb*	$\mathbf{dist_{(k),(N-1)}}$		*lsb*	(k+1)-th Row of the Distance Matrix
	msb	$\mathbf{dist_{(k),0}}$		*lsb*	*msb*	$\mathbf{dist_{(k),1}}$		*lsb*	
	msb	$\mathbf{dist_{(k),(N-2)}}$		*lsb*	*msb*	$\mathbf{dist_{(k),(N-1)}}$		*lsb*	
	msb	$\mathbf{dist_{(N-1),0}}$		*lsb*	*msb*	$\mathbf{dist_{(N-1),1}}$		*lsb*	Last Row of the Distance Matrix
	msb	$\mathbf{dist_{(N-1),2}}$		*lsb*	*msb*	$\mathbf{dist_{(N-1),3}}$		*lsb*	
Ceil(N^2/2)-1	*msb*	$\mathbf{dist_{(N-1),(N-1)}}$		*lsb*	*msb*	***0***		*lsb*	

N.B.: Ceil (x) is the smallest integer greater than or equal to x

Payload Size vs Network Size

Network Size = (NON)	Payload Size =	TOL Size +	DM Size
2	18	16	2
3	29	24	5
4	40	32	8
5	53	40	13
6	66	48	18
7	81	56	25
8	96	64	32
N	$8*N + Ceil(N^2/2)$	$8*N$	$Ceil(N^2/2)$

N.B.: Ceil (x) is the smallest integer greater than or equal to x

Mapping DM Row/Column Entries to Node Addresses

- **TOL and DM indices correspond:**
  - The i-th TOL entry contains the STANAG 5066 address of the 'from'-node in $dist_{i,j}$ and the 'to' node in $dist_{j,i}$
- **Manipulation of the TOL and DM *must* preserve this correspondence, e.g.,:**
  - insertion of a newly-joined network node into the TOL, shall result in the insertion of corresponding row and column elements in the DM;
  - deletion of a node from the network shall result in the deletion of the node from the TOL and the corresponding row and column elements in the DM;
  - re-ordering of the TOL (e.g., to implement a more efficient transmit sequence) shall result in a re-ordering of the corresponding row and column elements of the DM.

Three Cases/Scenarios that Elicit Change

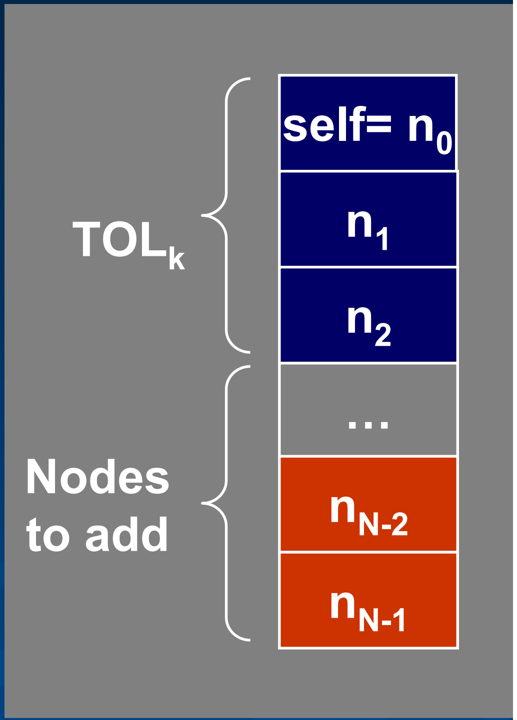
- **Scenario 1 (Joining Scenario):**
  - A node joins the network and thereby *must* be inserted into both the TOL and the DM;
- **Scenario 2 (Transient-Topology Scenario):**
  - Changes in the network topology *may* result in changes in the distance matrix and may force a change in the TOL, e.g., when a successor node becomes unreachable (even with relay);
- **Scenario 3 (TOL-Optimization Scenario):**
  - Sub-optimal TOL (e.g., TOL that use more token relays than necessary) *may* evolve in a network during Joining or Transient Topology scenarios, and reconfiguration of the TOL to obtain a shorter RCL *may* be performed when the network topology has stabilized.

Transmit-Order-List Optimization

- **TOL Recomputation**
  - The ring's TOL is recomputed only after the TOL and the DM have been stable for one or more ring cycles, i.e.,
  - A TOL is candidate for recomputation whenever:
    - $(\text{TOL, DM})_{\text{current}} = (\text{TOL, DM})_{\text{last}}$.   *and*
    - RCL > Number of Nodes = minimum RCL
- **Modified Nearest Insertion Method (MNIM)**
  - One method for finding approximate solutions to the travelling salesman problem, closely related to finding an optimal TOL
  - Effectively performs a virtual joining sequence (VJS), re-building the TOL by adding one node at a time.

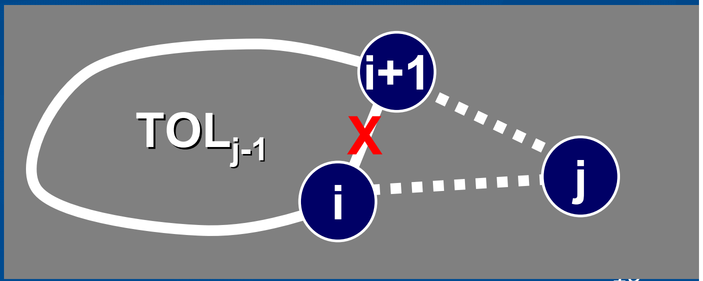
Virtual-Joining Sequence for TOL Reordering

- **Randomize the TOL, placing self at top of list**
- **$TOL_k = (n_0, n_1, n_2, \ldots, n_k)$**
  - the state of the transmit-order list after k nodes have been added,
- **randomly choose node n_j from the remaining nodes, and**
- **insert n_j between the two nodes n_i and $n_{((i+1) \bmod k)}$ that minimizes the increase in RCL, i.e., that minimizes:**



  - $\Delta RCL_j = dist(n_i, n_j) + dist(n_j, n_{((i+1) \bmod k)}) - dist(n_i, n_{((i+1) \bmod k)})$

- **Repeat until all nodes have been added**
- **On own RTT, forward as new TOL iff RCL less than current TOL**



Status and Way Ahead

- **Currently continuing requirements-capture and performance evaluation of the USN proposal**
  - Recent USN/AUSCANNZUKUS Risk-Reduction Limited-Objective Testing of the protocol at UHF shows good performance in a variety of 'challenging' scenarios … looking for wider release of results to NATO
  - detailed assessment at lower HF data rates needs to be performed to assess overhead impact
- **NC3A intends to develop ratification-draft re-write of Annex L incorporating multi-hop token-relay capability**
  - Protocol / algorithm / message usage appear conformant with current S'5066 Ed 3 roadmap for robust IP-over-wireless capability
  - Present draft to BLOSCOMMS 09 in March, ratification-draft submission in 3Q 2009 following further tests

Questions?