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**Industrial communication networks –**
**Fieldbus specifications –**

**Part 4-7: Data-link layer protocol specification – Type 7 elements**

# CORRIGENDUM 1

**Annex C – Topology of multi-segment DL-subnetwork**

*Replace the existing text of the annex by the following:*

## Annex C
(informative)

## Topology of multi-segment DL-subnetwork

### C.1 Introduction

This annex describes how to specify the topology of a multi-segment DL-subnetwork. The aim is to propose a data structure, which could be minimal while allowing correct operation of the bridge retransmission function.

The topology of a DL-subnetwork can first be specified globally, in order to verify a certain number of properties (topological connectivity, non-meshing, etc.); then on the basis of this specification the local data base specific to each bridge must be calculated in order to ensure it operates correctly.

Although this appendix proposes a method to achieve this goal, only the specifications of the data structures, global or local to each bridge, which define the DL-subnetwork topology, as well as the properties which it should fulfil, must be taken into account in the standard. The suggested method shows how to obtain a solution to the problem by taking into account certain optimization problems.

### C.2 Global specification

The topology of a multi-segment DL-subnetwork can be defined by the following elements:

— the set S of its segments: $S = \left\{ s_i \mid i \in [1, n] \right\}$

— the set B of its bridges: $B = \left\{ b_k \mid k \in [1, m] \right\}$

— and for each bridge of B, the data of a matrix $B^k$ of dimension n × n. whose coefficients $b_{ij}^k$ are defined by:

— $b_{ij}^{k} = 0$ if i = j;

— $b_{ij}^{k} = \infty$ if the bridge $b_k$ does not allow transfer of messages from segment $s_i$ to segment $s_j$ ;

— $b_{ij}^{k} = \alpha$ with $\alpha \in \mathbf{R}^{+*}$, if the bridge $b_k$ allows the transfer of messages from segment $s_i$ towards segment $s_j$, with $\alpha$ as load coefficient which allows taking into account of a different efficiency rate according to the transfers.

A load coefficient $b_{ij}^{k}$ can represent the load, as a rate of occupation of the medium, of the retransmission segment $s_j$. In reality, either the destination is directly $s_j$, or there are several paths possible, passing through intermediate segments, to reach $s_j$ and in this case the choice shall be to pass by the least loaded path.

It is of course possible to take as coefficients the same value (1 for example).

If a bridge allows two-way retransmission with the same load coefficient for the two directions, its matrix is symmetrical.

The matrix $B^k$ of a bridge also allows knowing all the segments to which it is connected:

— either in reception, $S_r^k$ = { segments whose corresponding line in the matrix includes at least one non-null finite coefficient}; note $n_r^k$ = card ($S_r^k$),

— or in transmission, $S_e^k$ = {segments whose corresponding column in the matrix includes at least one non-null finite coefficient}; note $n_e^k$ = card ($S_e^k$).

### C.3 Local specification

The information which a bridge must have locally allows it to answer the following question: when I receive a message on a segment $sr_i \in S_r^k$ destined for another segment $s_j$, must I do nothing or must I retransmit on segment $se_h \in S_e^k$).

To fulfil this purpose, it is enough to allocate to each bridge $b_k$ a transfer matrix $T^k$ with dimensions $n_r^k \times$ n, whose elements $r_{ij}^{k}$ are defined by:

— the line index $i \in [1, n_r^k]$ references segments $sr_i$ connected in reception ($\in S_r^k$),

— the column index j $\in [1, n]$ references the segments $s_j$ of the DL-subnetwork ($\in S$),

— $r_{ij}^{k} = 0$ if on reception of a message on segment $sr_i \in S_r^k$ addressed to segment $s_j$, the bridge shall not do anything, either because $s_j$ cannot be reached via this bridge, or because $sr_i = s_j$ (a bridge shall not retransmit a message received from a segment towards this same segment),

— $r_{ij}^{k} = se_h$ , with $se_h \in S_e^k$ , if on reception of a message on segment $sr_i \in S_r^k$ addressed to segment $s_j$, the bridge must retransmit to segment $se_h$.

NOTE Indexes i and h correspond to channel numbers whereas $sr_i$ is the segment connected in reception to channel i and $se_h$ is the segment connected in transmission to channel h.

## C.4 Properties

The properties which should satisfy the DL-subnetwork are topological connectivity and non-meshing.

Topological connectivity consists in ensuring that there is always a path from any given segment of $S$ to any other segment of $S$.

Non-meshing consists in ensuring that the transmission of a message from a transmitter located on segment $s_e$ and addressed to a receiver located on segment $s_r$ can be routed by only one path (thus preventing the message from being received more than once).

In fact, it is the definition of the local specification of each bridge and the calculation of its transfer matrix which ensure this property: by definition, on reception of a message on segment $sr_i$ addressed to segment $s_j$, either the bridge does not retransmit it, in particular if segment $sr_i$ is equal to segment $s_j$, or the bridge retransmits it on a single segment $se_h$, whereas by calculation of the matrix, it is necessary to make sure that one and only one bridge, connected in reception to segment $sr_i$, retransmits the message.

## C.5 Methods

The method consists in calculating the matrix $C$ of the minimum loads of the paths between any two segments. By this way we check the topological connectivity since none of these coefficients is infinite.

The second stage consists in calculating the transfer matrix of each bridge so that this gives the global DL-subnetwork the property of non-meshing while preserving the property of topological connectivity.

### C.5.1 Minimum load matrix

a) Load matrix of rank P

Definition: the load matrix of rank P, $C^P$, with dimensions $n \times n$, is the matrix whose coefficients $c_{ij}^P$ give the minimum load to travel from segment i towards segment j by passing via not more than P bridges.

We have:

— $c_{ii}^P = 0$ ;

— $c_{ij}^P = \infty$ , if there is no path from segment i to segment j by passing via not more than P bridges;

— if $c_{ij}^P$ is finite, the optimal corresponding path includes not more than P bridges (it can include less than P).

Obtaining by recurrence:

— The coefficients $c_{ij}^1$ of the load matrix of rank 1, $C^1$, are given by:

$$c_{ij}^1 = \min_{k \in [1, m]} \left( b_{ij}^k \right)$$

We have:

— $c_{ii}^1 = 0$ ;

— $c_{ij}^{1} = \infty$, if there is no permanent bridge allowing transfer from segment i towards segment j ;

— $c_{ij}^{1}$ is finite, if there exists one or more bridges allowing the transfer from segment i towards segment j.

— The coefficients $c_{ij}^{P}$, for P > 1, of the load matrix of rank P, $C^P$, are given by:

$$c_{ij}^{P} = \min_{k \in [1\ ,m]} \left(c_{ik}^{1} + c_{kj}^{P-1}\right)$$

In reality, the minimum load between two segments i and j passing via P bridges corresponds to a path composed of:

— a bridge allowing the passage from segment i to segment k, with a minimum load $c_1$,

— and a path with minimum load $c_2$ between this segment k and segment j, passing via P-1 bridges.

The intermediate bridge is additionally selected so that $c_1 + c_2$ is minimal.

b) Minimum load matrix

Definition: the minimum load matrix *C*, dimension n × n, is the matrix whose coefficients $c_{ij}$ give the minimum load to go from segment i to segment j. We thus have:

— $c_{ii} = 0$ ;

— $c_{ij} = \infty$ , if there is no path from segment i to segment j ;

— if $c_{ij}$ is finite, there is a path of length L ($s_1, s_2, \ldots , s_L$) with $s_1 = i$ and $s_L = j$, passing via bridges $b^{k_h}$, h ∈ [1, *L* - 1], whose load is $c_{ij}$ with:

$$c_{ij} = \sum_{h=1}^{h=L-1} b_{s_h s_{h+1}}^{k_h}$$

By definition the topological connectivity is well ensured by the fact that all the minimum load matrix coefficients *C* are finite.

Property: the minimum load matrix *C* is the limit of the load matrixes of rank P, when P tends to infinity:

$$C = \lim_{P \to \infty} C^P$$

In reality, the series $C^P$ is stationary, at least from rank m, where m is the number of bridges. A path which passes via more than m bridges passes at least twice via the same bridge and cannot thus have a minimum load.

Suppose Q the row from which the $C^P$ series is stationary ($C^{Q+1} = C^Q$).

### C.5.2 Calculation of the transfer matrices

Suppose now that the DL-subnetwork is topologically connected.

The transfer matrices $T^k$ are calculated by iteration according to the number P of bridges, from 1 to Q, requiring a minimum load path from a source segment s and a destination segment d.

At the start, $T^k = 0$ for every k.

The transfer matrix coefficients are referenced in the same manner as in C.3, that is:

— the line index i $\in [1, n_r^k]$ references the $sr_i$ segments connected in reception ($\in S_r^k$),

— the column index j $\in [1, n]$ references the $s_j$ segments of the DL-subnetwork ($\in S$).

a) Passage of a segment s to a segment d via 1 bridge

For all pairs of segments s and d such that $c_{sd}^1$ is finite,

for one and only one k (as selected) such that $c_{sd}^1 = b_{sd}^k$ ,

the following assignment is performed for the transfer matrix $T^k$:

— for i $\in [1, n_r^k]$ such that $sr_i = s$ and for j $\in [1, n]$ such that $s_j = d$ , then $r_{ij}^k = s_j$ .

b) Passage of a segment *s* to a segment d via P bridges

For every pair of segments *s* and d such that $c_{sd}^P$ is finite whereas $c_{sd}^{P-1}$ is infinite,

for one and only one k (as selected) such that $\exists\, s' \,\middle|\, c_{sd}^P = b_{ss'}^k + c_{s'd}^{P-1}$,

the following assignment is thus performed for the $T^k$ transfer matrix:

— for i $\in [1, n_r^k]$ such that $sr_i = s$ and for j $\in [1, n]$ such that $s_j = d$ , then $r_{ij}^k = s_h$ with $s_h = s'$

In the last two paragraphs, the bridge k which verifies the necessary property is not necessarily unique, but an assignment must be made for a single bridge to ensure the property of non-meshing.