Token Ring

Principles, Framing
and Management

Agenda

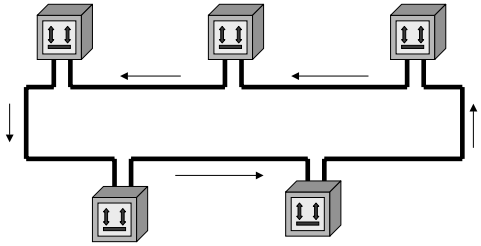
- Introduction
- Station States and Access Control
- Framing
- Token Ring Management

802.5 Token Ring

- all stations are actively (=interruptively) connected to the ring-network
- every station acts as intermediate amplifier (repeater)
- ring network is basically build as a series of unidirectional point to point connections
- failure of a station would be fatal because of its active coupling
- therefore stations are not directly connected to the ring, but over a bypass relay

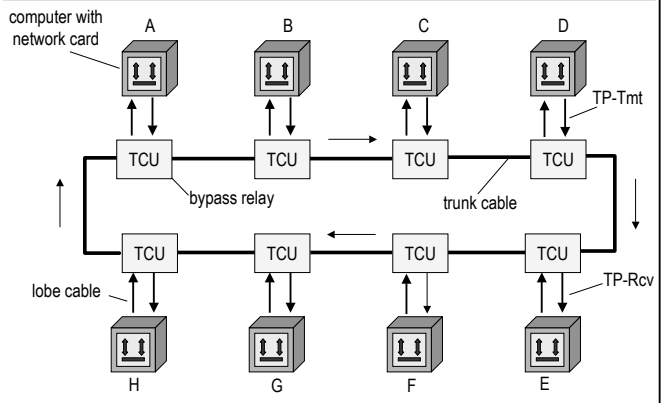
  --> TCU Trunk Coupling Unit

Token Ring Basic Idea



- active, interruptive coupling on a shielded twisted pair (TP) cable
- 4/16 Mbit/s bit rate, diff. Manchester coded, base band transmission
- unidirectional signal propagation along the ring

Bypass-Relay Technique



Trunk Coupling Unit

- TCU
  - passive bypass relay, powered by the network station
  - on station failure, the relais falls back in a neutral position and bypasses the trunk line
  - activating a station means closing the relais and hence the station becomes an active part of the ring
- problem:
  - transmitting power of a network card (to supply a point-to-point line) must be sufficient to supply the whole ring (lobe cables + trunk cable) in worst cases (e. g. only B and C active)
  - this results in a restriction for the maximal physical length of the ring: whole ring length must be less or equal the maximal possible distance between two ring stations

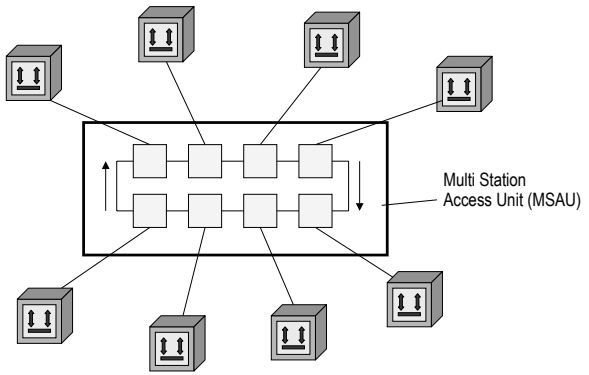
Token Ring Line Length

- 802.5 specifies
  - no maximal line lengths (in contrast to 802.3)
  - but a minimal signal quality at the receiver
- signal quality
  - can be achieved by a proper combination of transmitting power, cable quality and receiver sensivity
  - depending on vendor and cable type the maximal distance between two stations and also the maximal number of stations on the ring can vary
    - **4 Mbit/s: max 385m, max 260 stations (STP)**
    - **16 Mbit/s: max 173m, max 136 stations (STP)**
    - **in all other cases (e.g. UTP) at least 100m**

Line Lengths

- complex task
  - to calculate allowed link lengths, if a cable is spanned somehow in a building
- solution
  - structured cabling
  - concentration of TCUs in the center by using a MSAU
    - Multi Station Attachment Unit
  - MSAUs are coupled via double-rings using RI/RO-technique
- rule of thumb for structured cabling
  - distance between network stations and center must not exceed 100m

MSAU



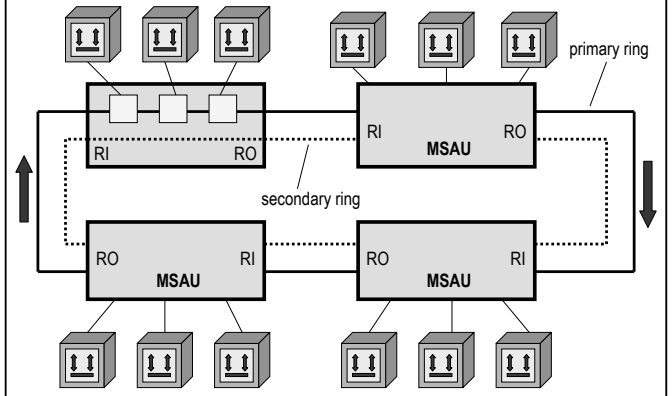
MSAU Coupling

- MSAU provides
  - only a limited number of lobe-connectors
- Ring-In/Ring-Out ports allow
  - coupling of several MSAUs by a double ring to increase the number of ports
  - double ring can bypass a broken trunk cable
- MSAU either passive or active
  - passive MSAU contains only passive bypass-relays
    - no amplification for RI/RO lines and lobe lines
  - active MSAU contains amplifier for RI/RO
    - hence Ring could be expanded as far as technology allows
    - with FO several kms

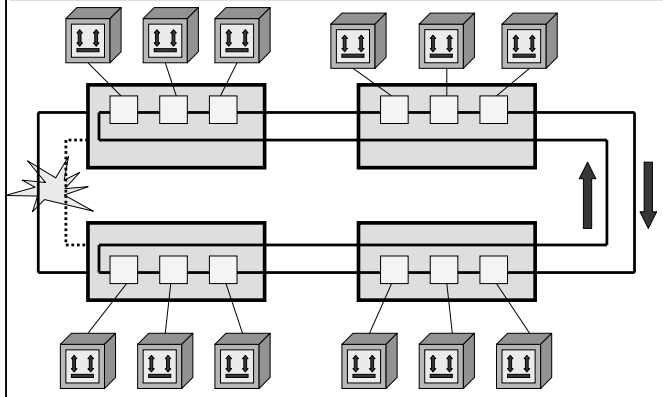
MSAU Coupling

- RI/RO technique
  - normally only the primary ring is used
  - if a trunk line fails, the MSAUs which are closest to the failure will connect primary and secondary ring together
  - hence full connectivity is reestablished
  - can be done automatically or manually
    - depending on the MSAU-type
    - e. g. by removing the broken trunk line from the corresponding passive MSAUs

RI/RO Technique



Failure Scenario



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States of a Token Ring Station

- during normal operation a token ring station is in one of 3 states:

1) repeater-state:
  - incoming bit stream is regenerated and passed to outgoing line (1 bit delay time)

2) insert-state:
  - ring is broken by the station and bits from the transmit-FIFO of the station are passed to the outgoing line; incoming bits are absorbed by the receive-FIFO
  - active transmitting mode
  - token ring becomes a loop

States of a Token Ring Station

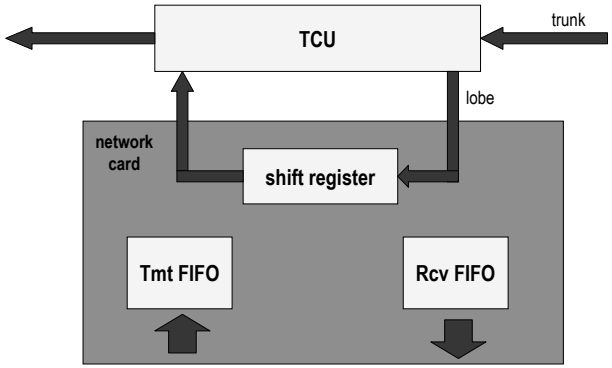
- states cont.:

3) copy-state:
  - like repeater function but additionally the bitstream is copied in the receive-FIFO
  - active receiving mode
  - FIFO … First In First Out buffer

- recognize: if a token ring station transmits a frame, the ring becomes a loop and hence the transmitted frame is removed by the emiting token ring station, all other stations are in repeater state and the addressed station makes a copy of the frame on the fly

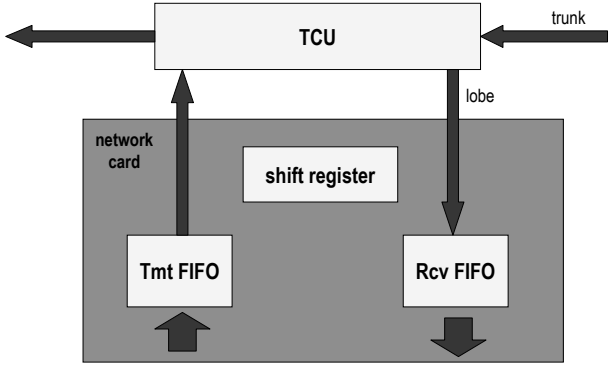
L24 - Token Ring

Repeater-State



 Token Ring, v3.4 17

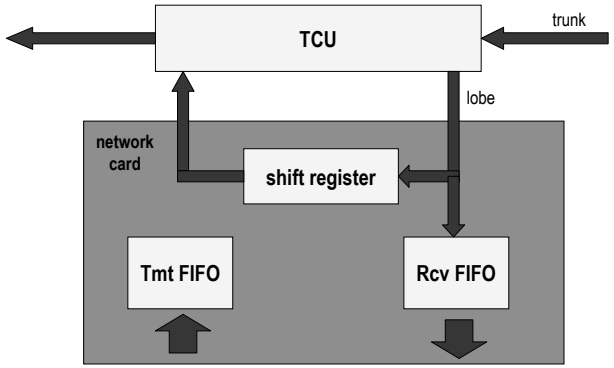
Insert-State



 Token Ring, v3.4 18

L24 - Token Ring

Copy-State



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Access Method: Token

- if no station wants to send, the token frame circulates around the ring
- station gets permission to send after receiving a token
- holding the token, the network station is allowed to send data for a certain duration
  - duration: token rotation time (default 10ms)
  - can send one or more frames in this time
  - therefore max. frame size: about 4500 Byte (4Mbit/s), about 18000 Byte (16Mbit/s)
- after that, the token is passed to the next station on the ring
  - deterministic method (Round Robin)

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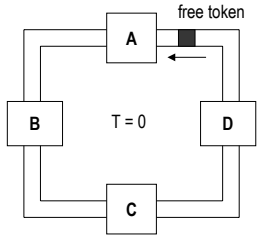
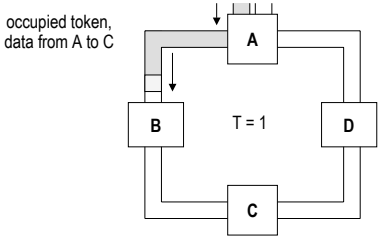
Token Method 1



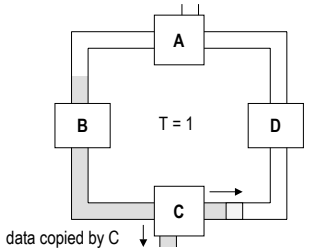
- token (T=0) circulates around the ring, no station has a frame to send
- all stations are in repeater-mode

Token Method 2



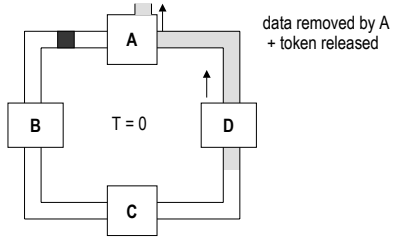
- station A receives token, breaks up the ring and inserts its frame (containing source-address A and destination-address C; token bit T ís set to 1)
- station A in insert-mode
- stations B, C and D in repeater-mode

Token Method 3



- station B receives frame but is not addressed, so B remains in repeater-mode
- station C receives frame and is addressed, so C changes into copy-mode
- station D remains in repeate-mode

Token Method 4



- station C has received the whole frame
- station A removes its frame, generates a new token and changes into the repeater-mode
- time for generation of new token: at 4 Mbit/s after receiving the whole frame, at 16Mbit/s after receiving of frame header or with ETR option (Early Token Release) immediately after emitting the frame

Ring Length and Bit Length

- the physical length of a single bit
  - about 50m for 4 Mbit/s
  - about 12,5m for 16 Mbit/s
    (remark: signal propagation speed is 0,66c)
    (remark: for 10 Mbit/s Ethernet about 20m)
- token frame
  - length 24 bit
  - needs a physical ring length of 1200m (4Mbit/s) and 300m (16Mbit/s)
    - worst case: only one active station
  - therefore one selected station (active monitor) inserts a constant 24-bit shiftregister into the ring

Tasks of the Active Monitor 1

- active monitor
  - provides the clock for all stations
- all other stations
  - recover the clock via PLL from the received data stream
  - the recovered clock is used as send clock to the downstream station
- number of stations and hence ring diameter is limitated
  - by jitter (accumulation of inaccuracy of clock caused by the sequence of PLLs)
- active monitor equalizes jitter effects
  - using an additional elastic shift register
    - 6 bits length -> tolerance of +/- 3 bits

Tasks of the Active Monitor 2

- token-management
  - generation of first token
  - regeneration of a lost token
  - monitors periodic token pass-by
- error-management
  - station sends too often or too long
  - station does not purge its emitted frame from ring
  - errors caused by activating/deactivating the bypass-relais
    - frame fragments
- special control frames (so called MAC-frames) are necessary for these tasks

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- Framing
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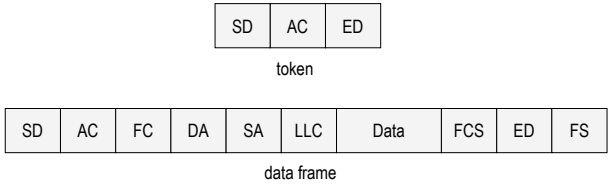
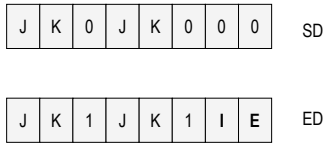
IEEE 802.5 Frame Structures



SD, ED ..... preamble/trailer for frame boundaries (8 bit)
AC ..... Access Control (8 bit)
FC ..... Frame Control (8 bit)
LLC ..... Header of LLC-layer (24/32 bit)
Data ..... payload
FCS ..... Frame Check Sequence (32 Bit)
FS ..... Frame Status (8 Bit)

Start/End Delimiter

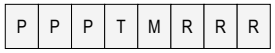


J, K ..... none-data symbols of diff. Manchester code
E ..... Error-detection bit
I ..... Intermediate-frame bit

Start / End Delimiter

- frame synchronization is done by code violation
  - J and K Symbols of the differential Manchester code
  - J and K -> no signal change in the middle of the bit
- E-bit is set by every station to indicate errors
  - sender clears E (E = 0)
  - every station performs FCS checking on the flly
  - E = 0 ... no error, E = 1 ... error
- I-bit indicates whether the frame is the last one of this series or if further frames have to be expected
  - I= 0 ... last frame, I = 1 ... further frames expected

Access Control

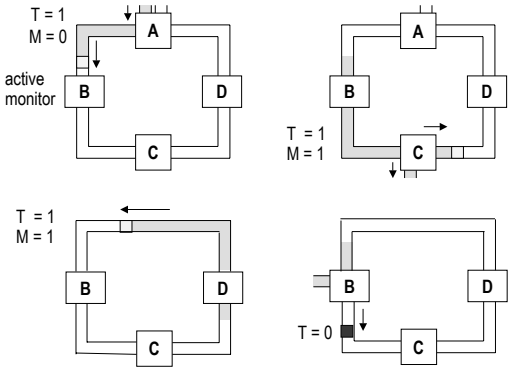


PPP ..... priority bits
T ..... token bit
M ..... monitor mit
RRR ..... reservation bits

Access Control

- T-bit defines
  - T= 0 ... token, T = 1 ... data frame
- M-bit enables the active monitor to detect and remove circulating frames
  - station sends frame with M = 0
  - active monitor sets M = 1 when the frame passes by
  - normally the sending station also removes frame from the ring
  - but if frame with M = 1 passes active monitor again an error has occured
  - active monitor removes this frame, cleans the ring and generates a new token

Monitor-Bit Handling



Access Control with Priority

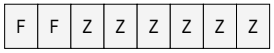
- PPP/RRR-bits allow implementation of an optional priority handling
  - PPP defines the current priority of the token or the data frame
    - PPP = 000 lowest priority
    - PPP = 111 highest priority
  - RRR enables a station to request a higher priority on the fly whenever a token or data frame passes by
  - station which currently holds the token increases after its data frame transmission the priority of the token according to the RRR-bits

Access Control with Priority

- now only stations, waiting to transmit a data frame with a this or a hígher priority, can catch the token
- all station with lower priority requests have to wait
- Round Robin among stations at a certain priority level
- after priority traffic is over, the station which has increased the priority („stacking station“) must also decrease the priority to the original value
- otherwise lower priority traffic would surrender

- with priority handling
  - the normal Round-Robin of token ring converts in a Round-Robin with 7 priority levels
  - seven parallel transmit-queues for data frames are used in a station

Frame Control

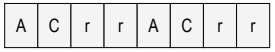


FF = 01 ..... LLC frame
FF = 00 ..... MAC control frame

ZZZZZZ ..... defines type of MAC control frame

bit pattern: type:
000011 .....claim token
000010 .....beacon
000100 .....purge
000101 .....active monitor present
000000 .....standby monitor present

Frame Status



A ..... address recognized
C ..... frame copied
rr ..... reserved

Frame Status

- the frame status signals a low-level acknowledgement for LLC frames
  - every frame is sent with AC = 0 0
  - station with address equal destination address sets A = 1
  - if this station can copy the frame in its internal FIFO-buffer it sets C = 1
  - otherwise C = 0 remains
  - by AC-bits the sender recognizes if target station is active on ring and if frame has been copied
  - doubling the AC - bits within frame status is done because of security reasons
    - FS is beyond the scope of FCS generation and control

Frame Status

- if station recognizes DA as own address and A is set: duplicate address problem on the token ring
  - this will be recorded by a counter
- possible combinations for AC:
  - AC = 00 ... addressed station not on ring
  - AC = 11 ... frame has been copied by addressed station
  - AC = 10 ... station on ring, frame not copied
  - AC = 01 ... invalid
- source routing bridges / transparent bridges must also set these bits even though they are not explicitely addressed
- other handling with MAC control frame

IEEE-MAC-Addresses (DA/SA)

I/G	U/L	b45,...,b44	.....	.....	....., b1, b0

destination address

RII	U/L	b45,...,b44	.....	.....	....., b1, b0

source address

I/G Individual /Group: I/G = 0 individual address,
I/G = 1 group broadcast

U/L Universal /Local: U/L = 0 global administered address by IEEE
U/L = 1 local administered address

all "1" address .... broadcast-address FFFF FFFF FFFF (hex)

second kind of broadcast address with U/L =1: C000 FFFF FFFF (hex)

RII Routing Information Indicator

Special DA

- null address:
  - by using the DA 0000 0000 0000 (hex) a station can send a frame to itself; no other station recognizes this address
- functional addresses:
  - special Token Ring multicast addresses for selecting specific functions
  - in the range of C000 xxxx xxxx (hex)
  - examples:

C000 0000 0001 (byte 5, bit 7) .... avtive monitor
C000 0000 0002 (byte 5, bit 6) .... ring parameter server
C000 0000 0008 (byte 5, bit 4) .... ring error monitor
C000 0000 0010 (byte 5, bit 3) .... configuration report server
C000 0000 0080 (byte 5, bit 0) .... NetBios
C000 0000 2000 (byte 4, bit 2) .... LanManager

Storage Format of 802.5 MAC-Address

- format of the IEEE 48 bit MAC-address on the medium:

I/G	U/L	b45, ..., b40	b39, ..., b32	.....	b15, ..., b8	b7, ..., b1, b0
0	1	00 1000	0000 0000	.....	0000 0000	1100 0001

- IEEE 802.5 sends the most significant bit of each octet at first
- so the 802.5 address storage format is equal to the IEEE address representation:

I/G	U/L	b45, ..., b40	b39, ..., b32	.....	b15, ..., b8	b7, ..., b1, b0
0	1	00 1000	0000 0000	.....	0000 0000	1100 0001

Frame Format with RII

RII = 0

MAC - H	DA	**0**	SA	LLC	Data	MAC - T

RII = 1

MAC - H	DA	**1**	SA	**Rout. Info**	LLC	Data	MAC - T

MAC - H .... MAC - Header (SD, AC, FC)
MAC - T .... MAC - Trailer (FCS, ED, FS)

Routing Information Indicator

- RII indicates
  - if additional routing information for source route bridging is available
  - RII = 0 ... frame without routing information
    - receiver of this frame is on the local ring
  - RII = 1 ... frame with routing information
    - routing information contains the source route for the frame or must be handled by source route bridges according to the type of the roting information
    - for details see source route bridging
    - receiver of this frame is on a different ring

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Token Ring Management

- token ring operations need management functions to initialize the ring and for error handling
  - active monitor has to be selected, activated in a station, and also supervised
  - after powering up a station, duplicate addresses must be detected (important for local administered addresses) and also an initialization might be necessary
    - Ring Parameter Server (RPS)
  - in case of a line break the location of the break should be signaled as accurate as possible
    - Ring Error Monitor (REM)
  - topology changes should be documented
    - Configuration Report Server (CRS)

Active Monitor Selection

- initializing
  - competition of all active stations for active monitor
  - all stations periodically send Claim-Token (CT) MAC-control frame by using their source-address as parameter
  - all stations are in insert-mode
  - on receiving a CT-frame with lower address as own address the station continues sending and remains in insert-mode
  - on receiving a CT-frame with higher address as own address the station stops sending and changes into repeater-mode
  - CT-frame remains unchanged when passing this station
  - on receiving a CT-frame with equal address as own address
  - active monitor found

Active Monitor Tasks

- supervision:
  - generation of the first token
  - control if token periodically passes the active monitor (timeout)
  - monitor-bit function to detect frame fragments, which have been originated by station breakdown or by powering-on new stations via bypass-relay
  - emitting an Active-Monitor-Present (AMP)-control frame every 7 seconds (heartbeat-function) and triggering a ring-wide Upstream-Neighbor-Address (UNA) determination
  - UNA is also called NAUN (Next Active Upstream Neighbor)

Active Monitor Tasks

- error handling:
  - if frame-fragments occur, the active monitor has to clean-up the ring with the Purge (PRG)-control frame and hereafter a new token has to be inserted
  - if there is no token on the ring an active monitor must be determined via claim-token procedure
  - this also resolves conflicts caused by stations which are continuously sending frames
  - stations which are continuously sending tokens (DTE jabbering) are detected by missing AMP-frames
- hardware aspects:
  - fixed and an elastic shiftregister, master clock

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Active Monitor <-> Standby Monitor

- all stations except active monitor become standby monitors:
  - control if AMP-frame and token are periodically passing by
  - on timeout, every station tries to become active monitor by using the claim-token-procedure
- upstream neighbors determination:
  - periodical AMP-frame triggers ring-wide determination of upstream-neighbors
  - every station maintains the address of the upstream-neighbor for signaling purposes in error situations and to provide statistical data for CRS

Upstream-Neighbor Determination

- AMP-frame is transmitted with frame status AC = 00 and DA = broadcast
- first station after active monitor sets AC = 11 and notes the source-address of the AMP-frame as Upstream-Neighbor-Address (UNA)
- adjacent stations do not interprete this frame with respect to UNA; AMP-frame is removed from the ring by the active monitor
- subsequently this station sends Standby-Monitor-Present (SMP) MAC-control frames with AC = 00 and DA = broadcast
- now the following station determines UNA with the same method and emits also the SMP-frame
- ...until all UNAs are found

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Inserting A Token Ring Station

- insertion procedure:
  - at first the station verifies its lobe line by sending a Lobe-Test (LT) control frame to the own address
  - hereon the bypass-relay is activated
  - waiting for the first token; then transmitting a Duplicate-Address-Test (DAT) control frame with AC = 00
  - on receiving the own DAT-frame with AC = 00, no station with this address exists on the ring -> insertion successful; Report-Ring-Station-Address (RRSA) control frame is sent to CRS
  - on receiving the own DAT-frame with AC = 11, duplicate address exists -> abort insertion

Beaconing

- transmitting a beacon
  - on fatal errors (e.g. no receive signal from upstream neighbor possible because of a line break, TCU-error) -> beaconing
  - Beacon-Superviory (BCN) control frame contains address of the station, specifies error type and also contains address of Upstream Neighbor (UN); BCN is sent periodically
  - if UN receives this frame, the station will be removed from the ring (by deactivating its bypass-relay) and a diagnosis will be performed
  - if BCN-frames arrive their home addresses, the error has been recovered by removing the UN

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Beaconing

- if error has been removed, a new active monitor is determined by using CT-frames and the ring is newly initialized
- if no BCN-frame arrives its home address within 16 seconds, the station removes itself from the ring and performs also a self-diagnosis
- stations which have finished their self-diagnosis successfully, are trying to return to the ring again (using the normal inserting procedure)
- during the beaconing-procedure other stations keep quiet

Further Control Frames

- station initialization using RPS:
  - request initialization
  - initialize ring station
- error monitoring using REM:
  - report soft error
  - report active monitor error
  - report neighbor notification incomplete
- network management using CRS:
  - report new monitor
  - report NAUN change
  - remove ring station
  - change parameters

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