LIN protocol description

LOCAL INTERCONNECT NETWORK

MOTOROLA
intelligence everywhere

digital dna

Automotive Body Network
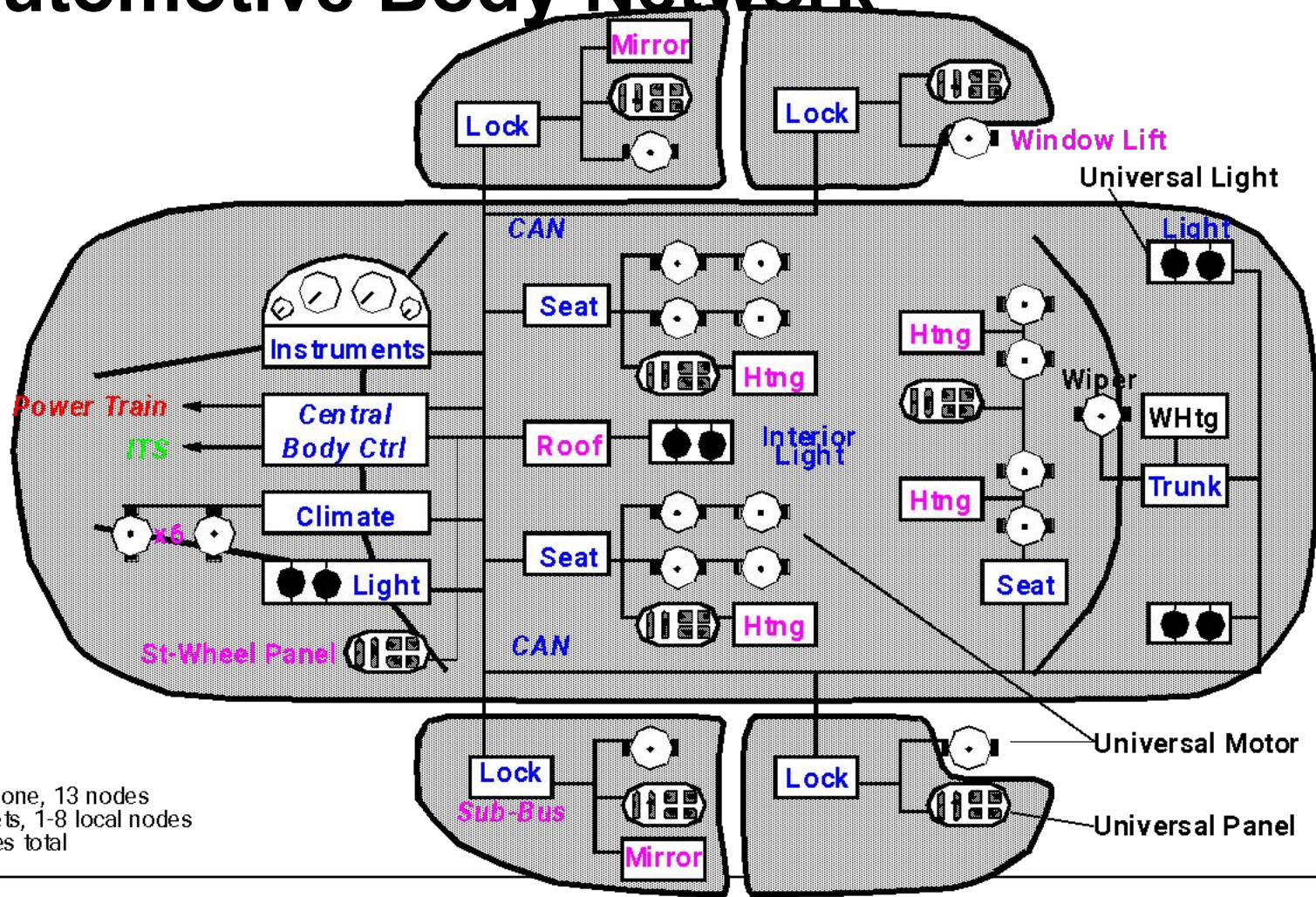
1 backbone, 13 nodes
8 subnets, 1-8 local nodes
52 nodes total

LIN – A Bus
W. Specks, A. C. Wense

MOTOROLA
intelligence everywhere

digital dna

Typical LIN Applications

Roof:
(high amount of wiring)
Rain Sensor, Light Sensor,
Light Control, Sun Roof
…
(Rain Sensor needs to be
interrogated every 10-20ms)

Steering Wheel:
(very many controls are going to be
positioned on the steering wheel)
Cruise Control, Wiper,
Turning Light, …
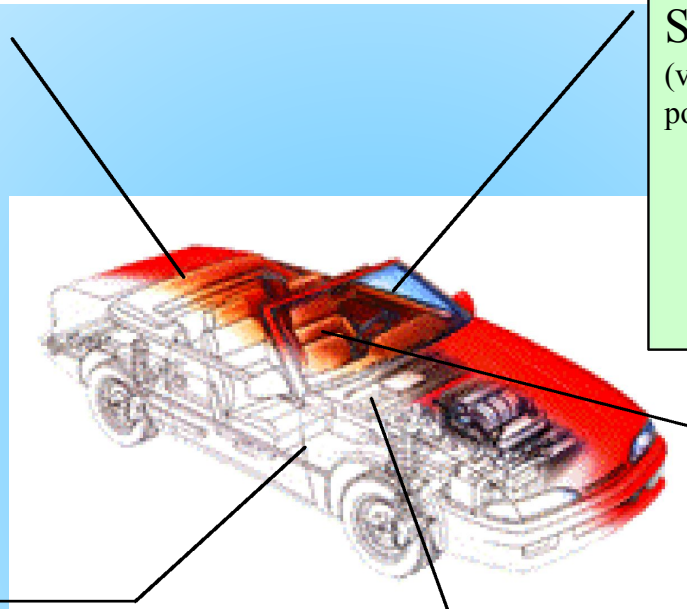Optional: Climate Control,
Radio, Telephone, etc.

Seat:
many Seat Position Motors,
Occupancy Sensor,
Control Panel

• **Door/window/seat:**
Mirror, Central ECU,
Mirror, Switch, Window
Lift,
Seat Control Switch,
Door Lock, etc.

Climate:
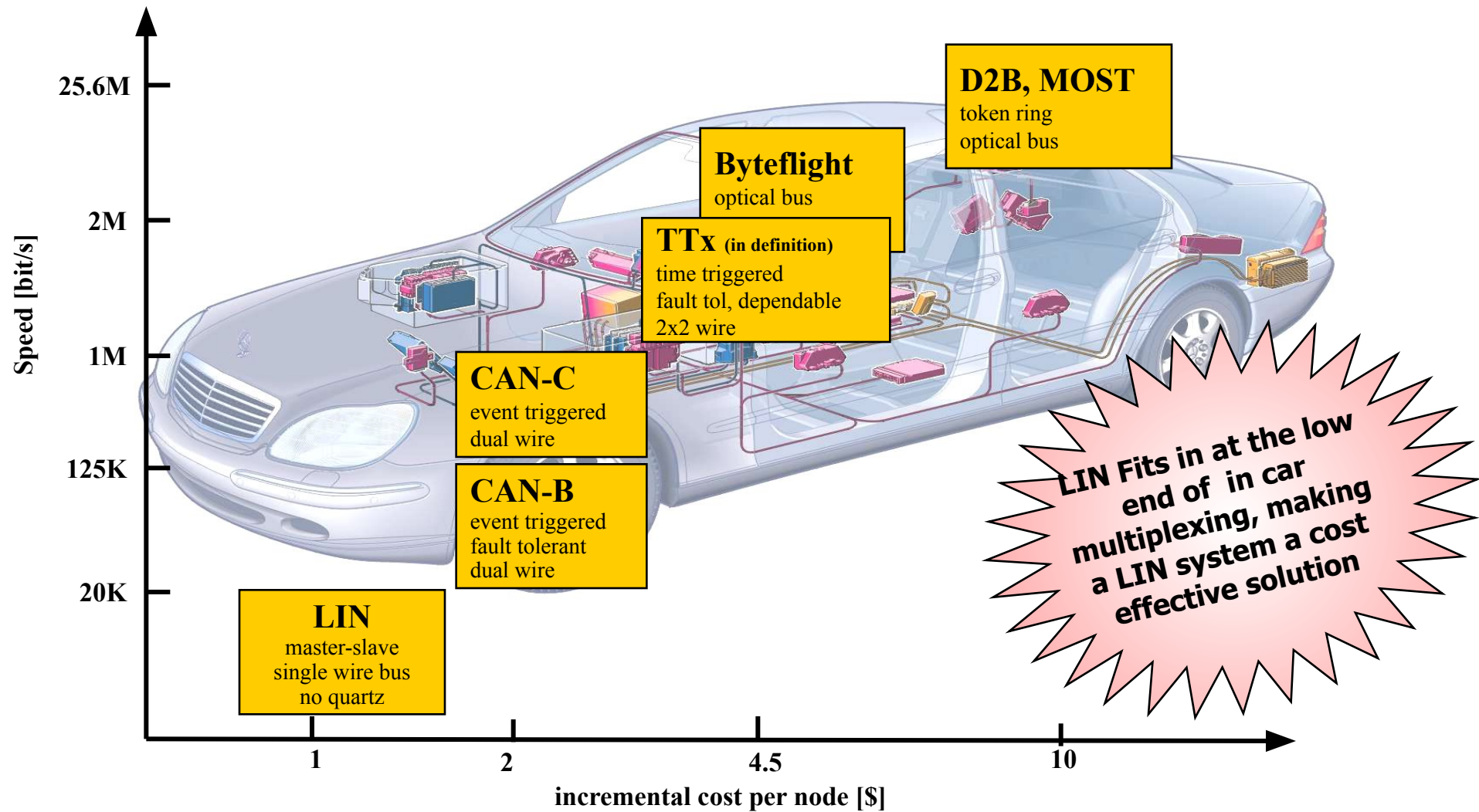many Small Motors
Control Panel

MUX Standards (Costs and Speeds)

Speed [bit/s] (vertical axis)

Axis values: 25.6M, 2M, 1M, 125K, 20K

incremental cost per node [$] (horizontal axis)

Axis values: 1, 2, 4.5, 10

D2B, MOST
token ring
optical bus

Byteflight
optical bus

TTx (in definition)
time triggered
fault tol, dependable
2x2 wire

CAN-C
event triggered
dual wire

CAN-B
event triggered
fault tolerant
dual wire

LIN
master-slave
single wire bus
no quartz

LIN Fits in at the low end of in car multiplexing, making a LIN system a cost effective solution

MOTOROLA
intelligence everywhere™

digital dna™

LIN Consortium

Consortium formed in 1998.
Five Car manufacturers
ONE Semiconductor Supplier (Motorola)
One tool Supplier (VCT)

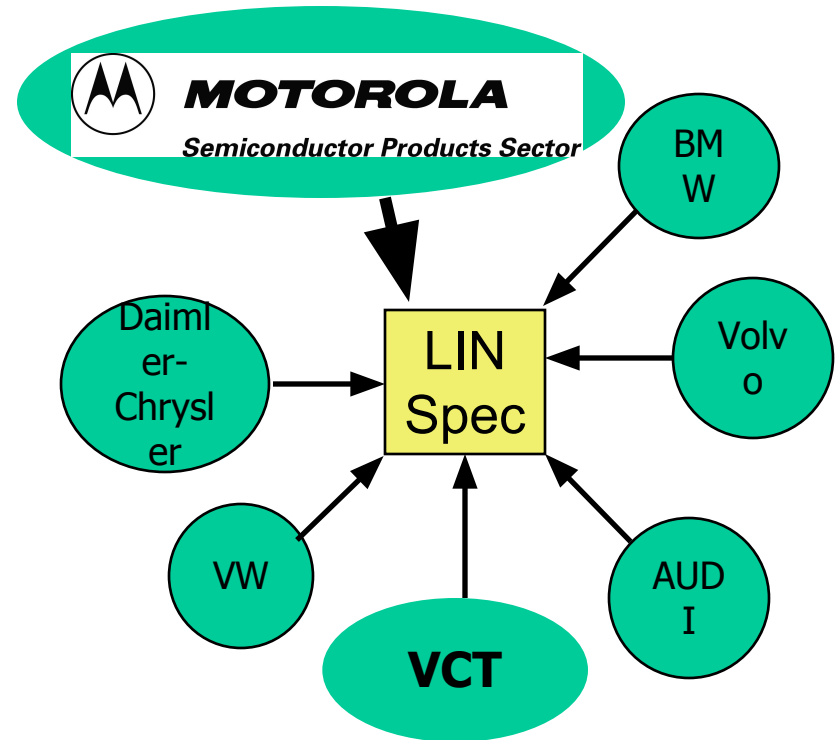Specification finalised on 02/02/00
Official Launch at SAE March '00
Open Specification.

Motorola Ready to support LIN with
    extensive
device families and new parts already in the
discussion/ spec finalization loop.
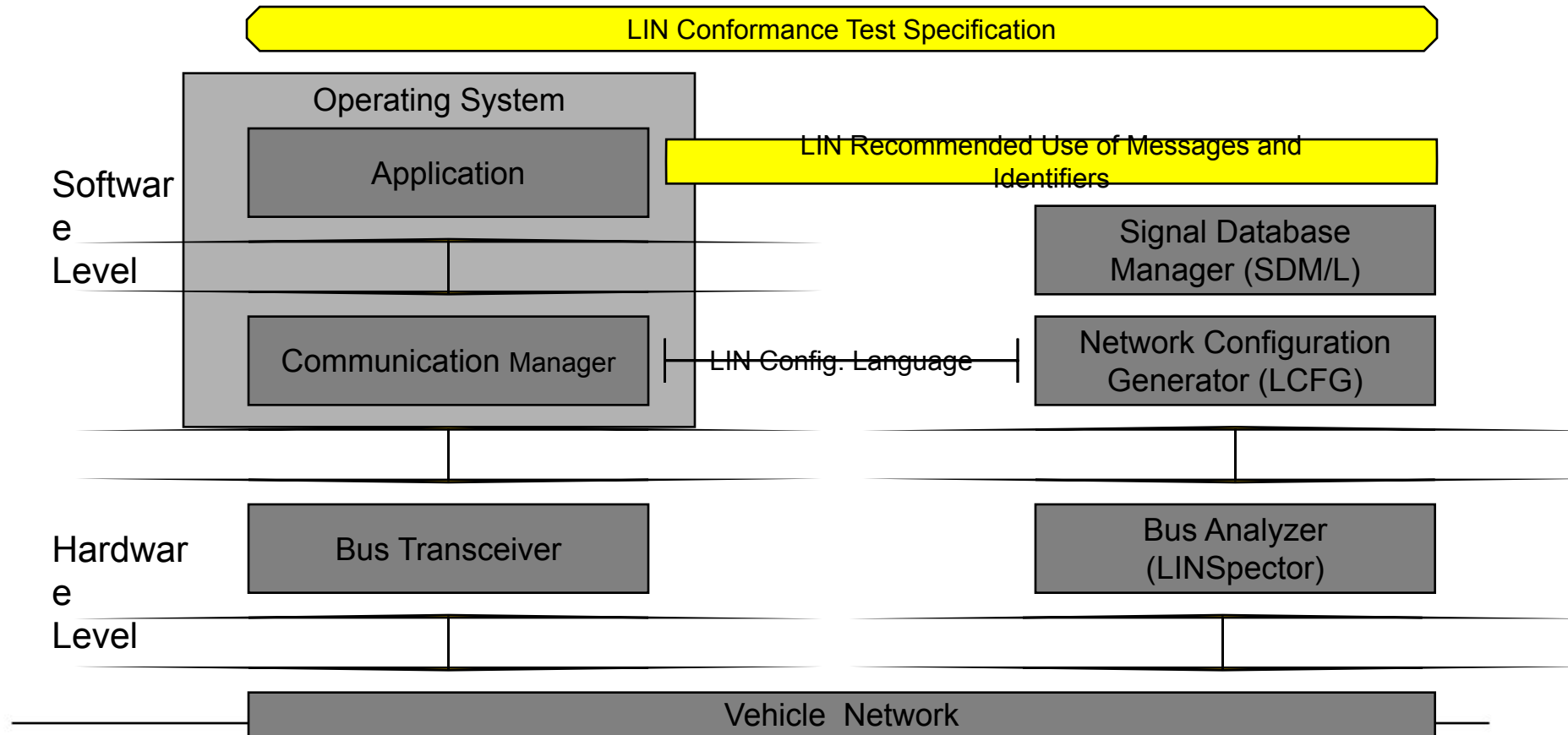First dedicated LIN part available Q3 '00

MOTOROLA intelligence everywhere™

digital dna™

LIN Standard - Overview

ECU
(LIN relevant
functions only)

Tools

LIN Conformance Test Specification

Operating System

Application

Software Level

LIN Recommended Use of Messages and Identifiers

Signal Database Manager (SDM/L)

Communication Manager

LIN Config. Language

Network Configuration Generator (LCFG)

Hardware Level

Bus Transceiver

Bus Analyzer (LINSpector)

Vehicle Network

MOTOROLA
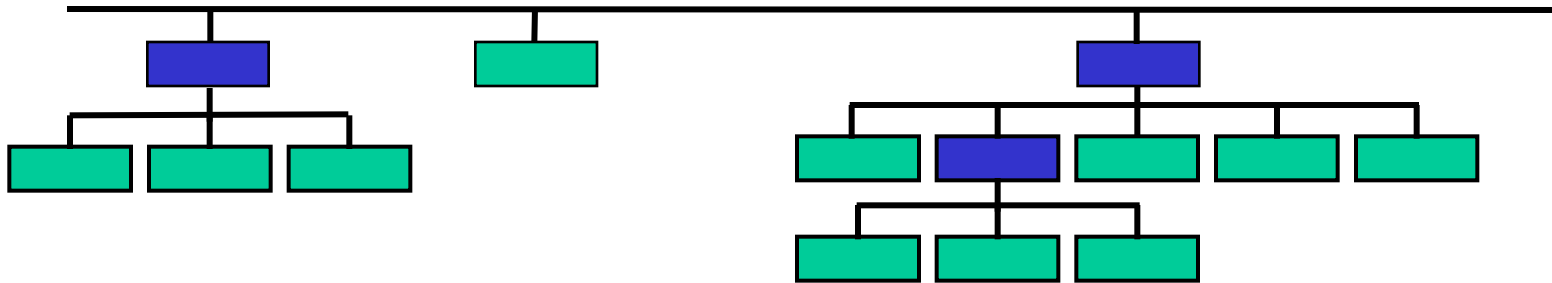intelligence everywhere™

digital dna™

Hierarchical Network Structure

Flat Network

Hierarchical Network

- Subnets are necessary to reduce Busload on main Bus

- Solution examples:

  - **CAN**
    - +Automotive Standard Bus
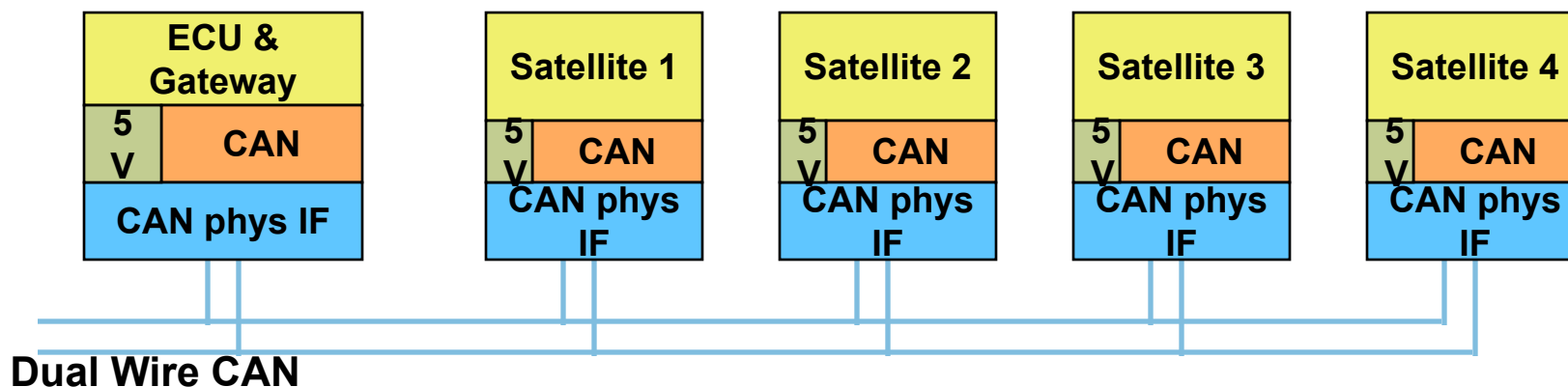   - +Compatible with Main Bus
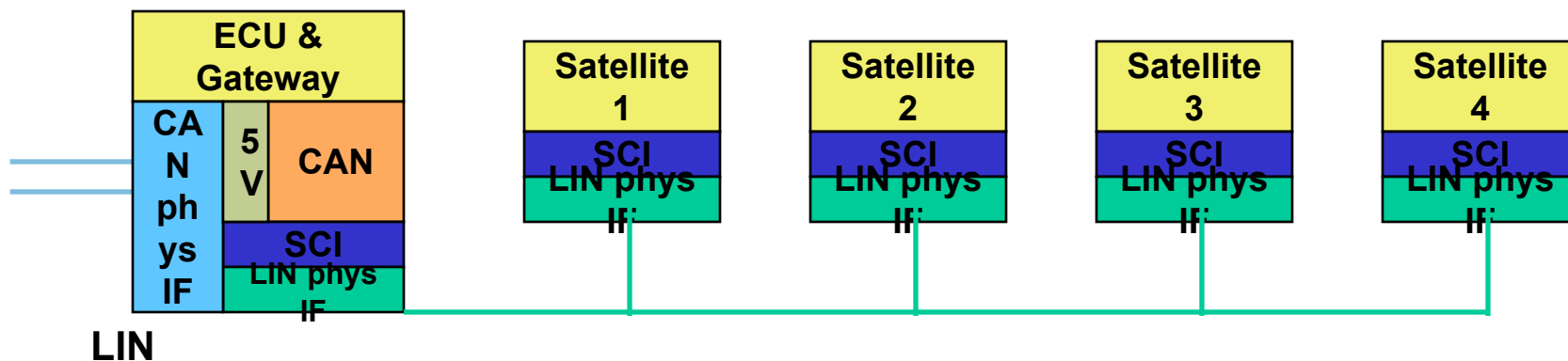   - -Expensive (Die Size/ Dual Wire)

- **Serial Sub Bus**
  - - no standard Bus System
  - - not compatible with Main Bus
  - + inexpensive
  - + SCI-Based: Interface exists even on cheap devices
  - + Interface can easily be reconstructed by ASIC or CPLD
  - + Protocol can be done in Software

MOTOROLA intelligence everywhere™

digital dna™

Sub-Network: LIN vs. CAN

LIN

ECU & Gateway		
CAN phys IF	5V	CAN
	SCI	
	LIN phys IF	

Satellite 1
SCI
LIN phys IF

Satellite 2
SCI
LIN phys IF

Satellite 3
SCI
LIN phys IF

Satellite 4
SCI
LIN phys IF

Dual Wire CAN

ECU & Gateway	
5V	CAN
CAN phys IF	

Satellite 1	
5V	CAN
CAN phys IF	

Satellite 2	
5V	CAN
CAN phys IF	

Satellite 3	
5V	CAN
CAN phys IF	

Satellite 4	
5V	CAN
CAN phys IF	

Cost Factors: CAN Module   Dual Wire Interface
Crystal   5V supply for bus
2nd Wire / Connector

MOTOROLA intelligence everywhere™   digitaldna™

SubNets

- Necessary to reduce Busload on main Bus
- Solutions
  - **CAN**
    - + **Automotive Standard Bus**
    - + **Compatible with Main Bus**
    - - **Expensive (Die Size/ Dual Wire)**
  - **Serial Sub Bus**
    - - **no standard Bus System**
    - - **not compatible with Main Bus**
    - + **inexpensive**
    - + **SCI-Based: Interface exists even on cheap devices**
    - + **Interface can easily be reconstructed by ASIC or CPLD**

MOTOROLA
intelligence everywhere

digital dna

Sub Bus Concept

- Basic Requirements:
  - **Satisfy Need for a Standard for Sub Busses**
  - **Cost driven: The solution must be cheaper than CAN**
  - **Reliability: Same Level as CAN expected**
  - **Long Term Solution**
  - **Logical Extension to CAN**
  - **Scalable: Capability to extend Systems with additional nodes**
  - **Lowering Cost of Satellite nodes:**
    - **No Crystal or Resonator**
    - **Easy implementation**
    - **Simple State Machines**
  - **Low Reaction Time (100 ms max)**
  - **Predictable Worst Case Timing**

MOTOROLA
intelligence everywhere™

digital dna™

LIN Concept

- ## Technical Solution
  - Low cost single-wire implementation (enhanced ISO 9141)
  - Speed up to 20Kbit/s (limited for EMI-reasons)
  - Single Master / Multiple Slave Concept
    - → No arbitration necessary
  - Low cost silicon implementation based on common UART/SCI interface hardware
    - → Almost any Microcontroller has necessary hardware on chip
  - Self synchronization without crystal or ceramics resonator in the slave nodes
    - → Significant cost reduction of hardware platform
  - Guaranteed latency times for signal transmission (Predictability)

MOTOROLA
intelligence everywhere™

digital dna™

Master / Slave Protocol

- ## Master Task

  - **Determines order and priority of messages.**
  - **Monitors Data and check byte and controls the error handler.**
  - **Serves as a reference with its clock base (stable clock necessary)**
  - **Receives Wake- Up Break from slave nodes**

- ## Slave Task

  - **Is one of 2-16 members on the bus**
  - **Receives or transmits data when an appropriate ID is sent by the master.**
  - **The node serving as a master can be slave, too!**

MOTOROLA
intelligence everywhere™

digital dna™

Master / Slave Protocol

- Master
  - **has control over the whole Bus and Protocol
    The master controls which message at what time is to be
    transferred over the bus. It also does the error handling.
    To accomplish this the master**
    - **sends Sync Break**
    - **sends Sync Byte**
    - **sends ID-Field**
    - **monitors Data Bytes and Check Byte, and evaluates them on
      consistance**
    - **receives WakeUp Break from slave nodes when the bus is
      inactive and they request some action.**
    - **serves as a reference with it's clock base (stable clock
      necessary)**

MOTOROLA
intelligence everywhere™

digital dna™

Master/Slave Protocol

- Slave
  - **Is one of 2-16 Members on the Bus and receives or transmits Data when an appropriate ID is sent by the master.**
    - **Slave snoops for ID.**
    - **According to ID, slave determines what to do.**
      - **either receive data**
      - **or transmit data**
      - **or do nothing.**
    - **When transmitting the slave**
      - **sends 1, 2, 4, or 8 Data Bytes**
      - **sends Check-Byte**
    - **The node serving as a master can be slave, too!**
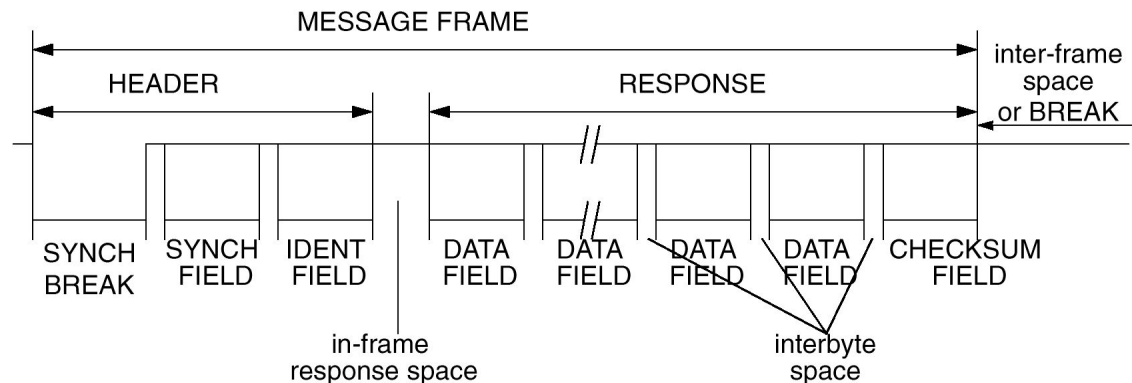
MOTOROLA
intelligence everywhere
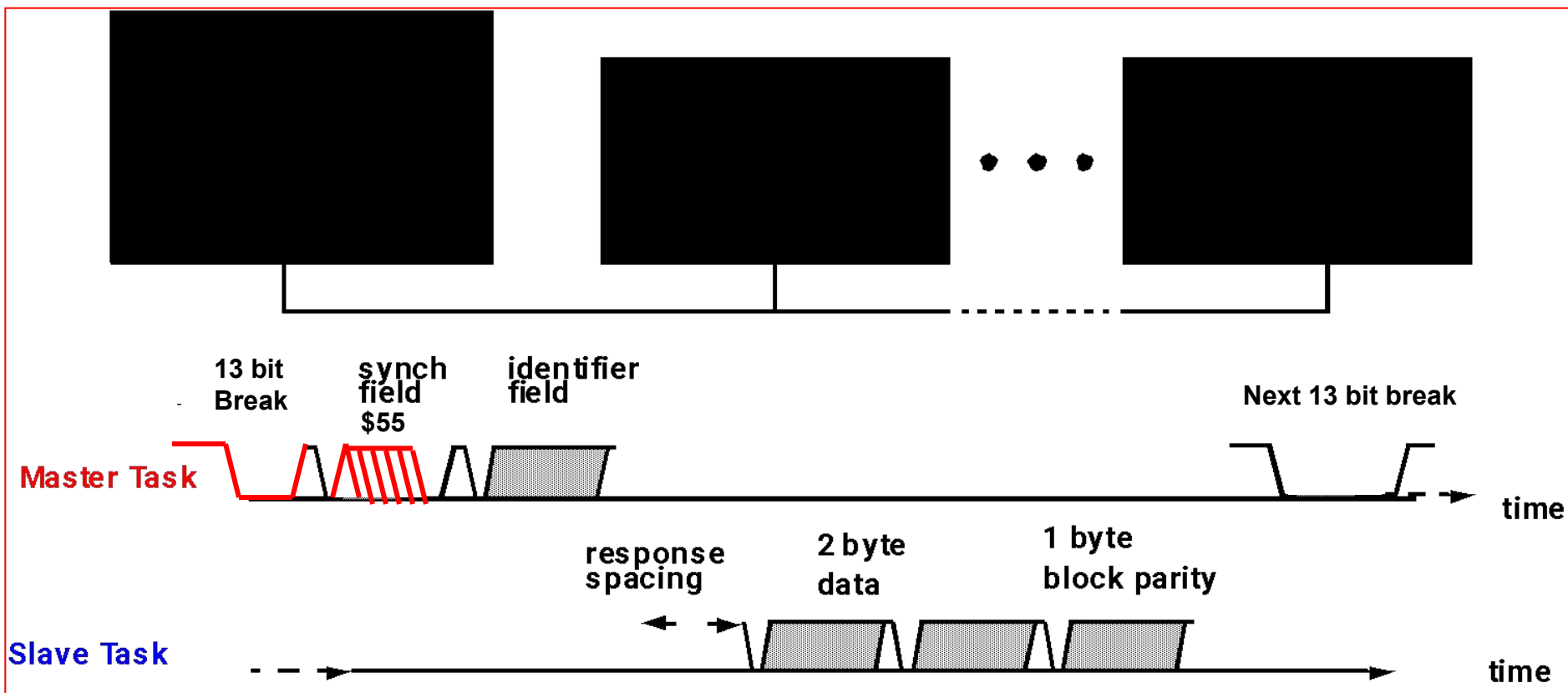
digital dna

...... protocol offers message timing predictability

Time Triggered Approach

- Message Length is known
    - **Number of transmitted data bytes is known**
        - → **minimum length can be calculated**
    - **Each Message has length budget of 140% of it's minimum length**
        - → **maximum allowed length is known**
        - → **distance between beginning of two messages**

MESSAGE FRAME

HEADER   RESPONSE   inter-frame space or BREAK

SYNCH BREAK | SYNCH FIELD | IDENT FIELD | DATA FIELD | DATA FIELD | DATA FIELD | DATA FIELD | CHECKSUM FIELD

in-frame response space

interbyte space

MOTOROLA
intelligence everywhere™

digital dna™

Data Transmission

13 bit Break

synch field $55

identifier field

Next 13 bit break

Master Task

time

response spacing

2 byte data

1 byte block parity

Slave Task

time

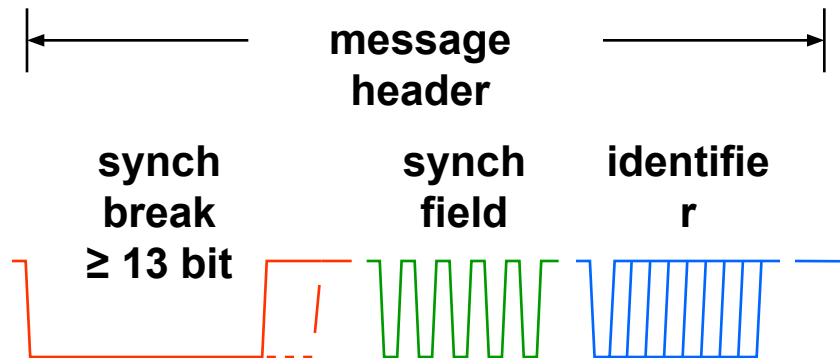**MOTOROLA** intelligence everywhere™

digital dna™

Message Frame

- ## Synch Byte:
  - **Specific Pattern for Determination of Time Base (Determination of the time between two rising edges)**
  - **A Synch Byte precedes any Message Frame**

- ## ID-Field:
  - **Message Identifier: Incorporates Information about the sender, the receiver(s), the purpose, and the Data field length. Length 6 Bit. 4 classes of 1/2/4/8 Data Bytes. The length coding is in the 2 LSB of the ID-Field. Each class has 16 Identifiers. A total of 64 Message Identifiers are possible.**
  - **2 Parity Bits protect this highly sensitive ID-Field.**

MOTOROLA
intelligence everywhere

digital dna

Identifier

- The identifier field is sent by the master node to all LIN nodes
- This identifier normally contains one of 64 different values and includes 2 parity bits in the 8 bit data
- The identifier is normally associated with a collection of signals that are subsequently transmitted on the LIN bus
- In a specific case this can initiate SLEEP mode in the LIN slave nodes – in this case no further data is transmitted on the LIN bus


message header

synch break ≥ 13 bit

synch field

identifier

MOTOROLA intelligence everywhere™

digital dna™

LIN Message Frame

message header | message response

| synch break ≥ 13 bit | synch field | identifier | 0 to 8 data fields | checksum |

byte field
SCI / UART format

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |

start   LSB   stop

MOTOROLA intelligence everywhere™

digital dna™
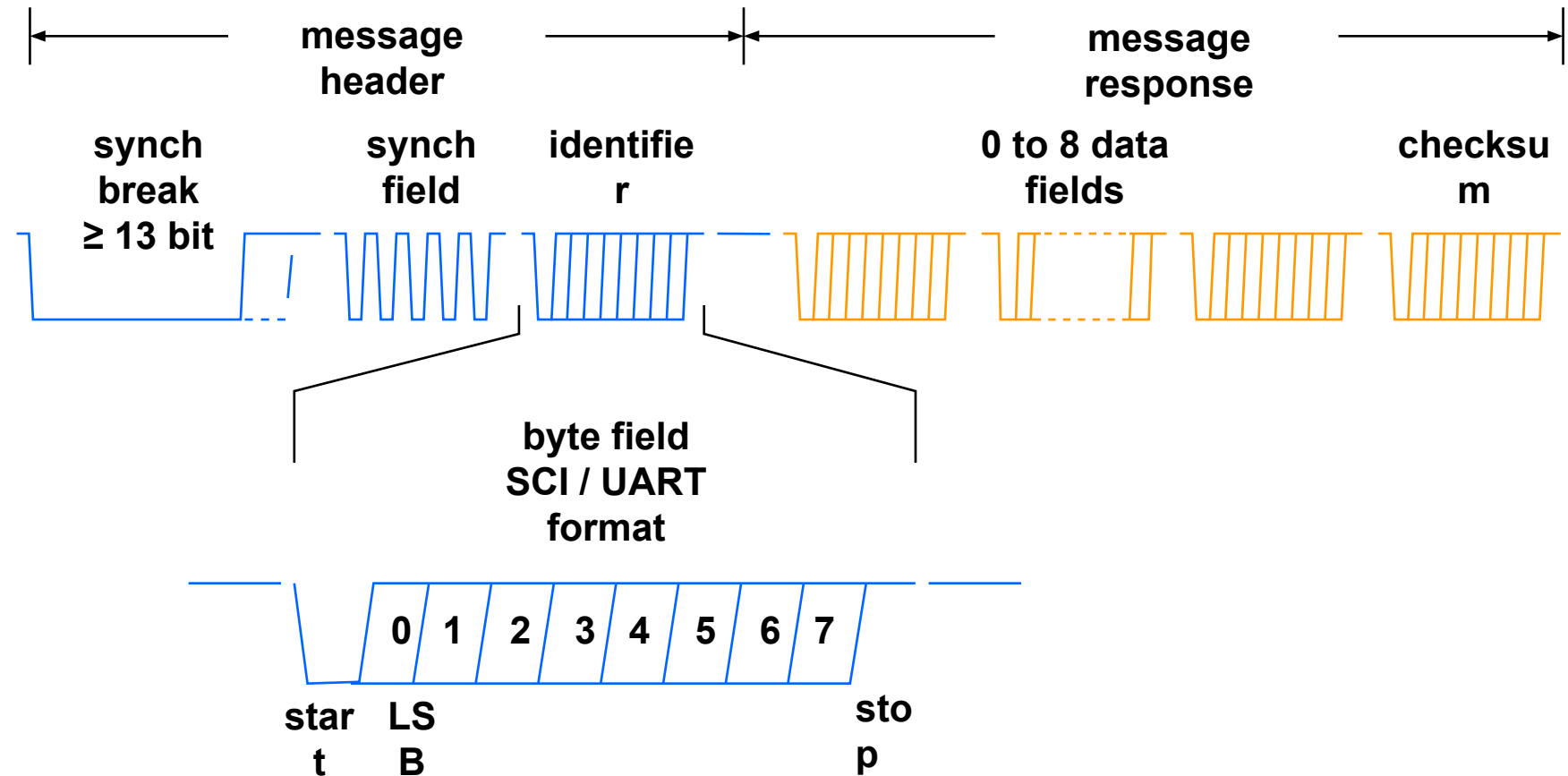
LIN Communication - Data from Slave to Master

Master Node
- LIN Master Task
- Slave Task Rec
- Slave Task Trans

quartz

Slave Node
- Slave Task Rec
- Slave Task Trans

identifier → synch field → synch break →

← data byte ← data byte ← checksum
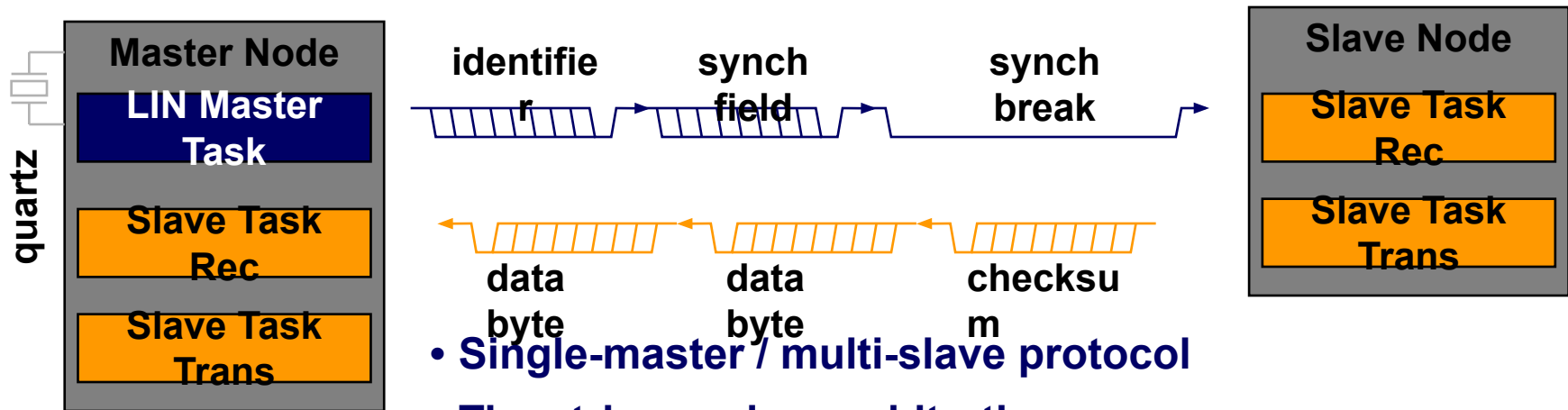
- **Single-master / multi-slave protocol**
- **Time triggered, no arbitration**
- **Identifier denotes message content, not physical address**
- **Multicast messages**
- **Baud rate synchronization through protocol**
- **Power saving sleep mode**

MOTOROLA intelligence everywhere™

digital dna™

LIN Communication - Data from Master to Slave(s)
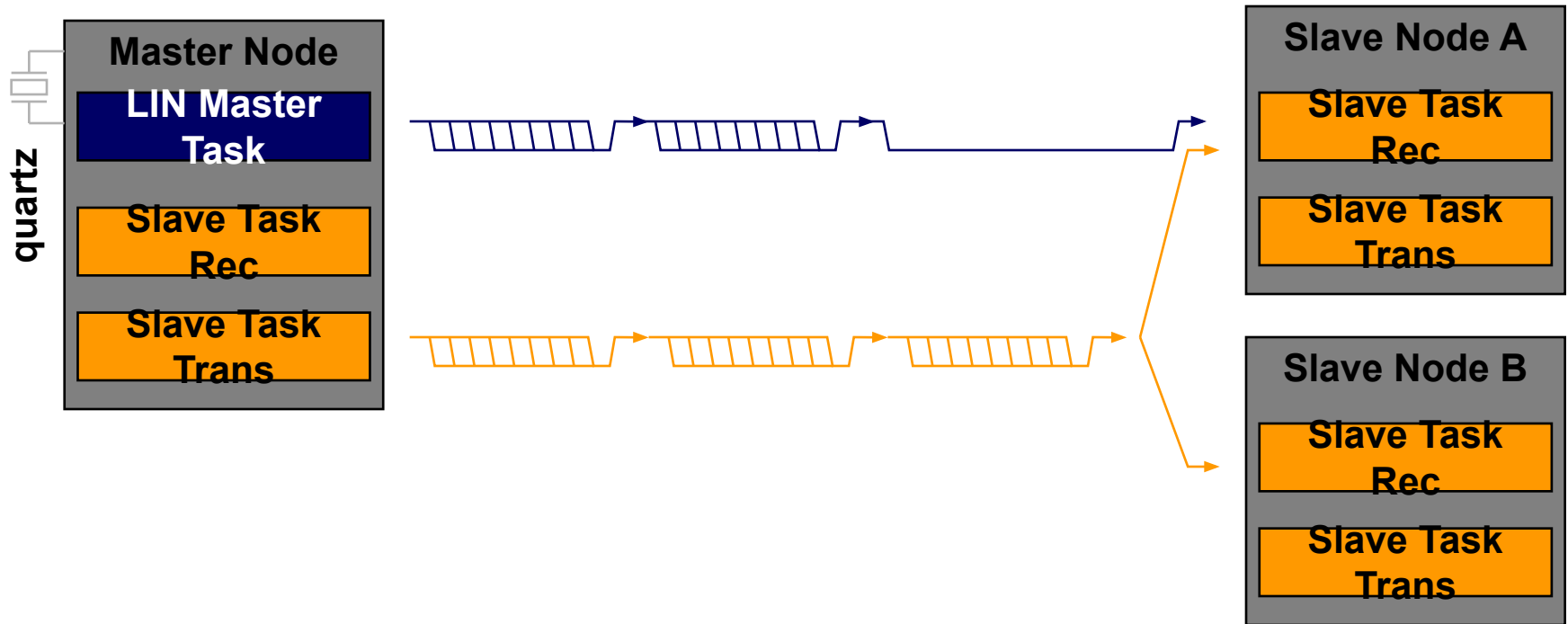
LIN Communication - Data from Slave to Slave
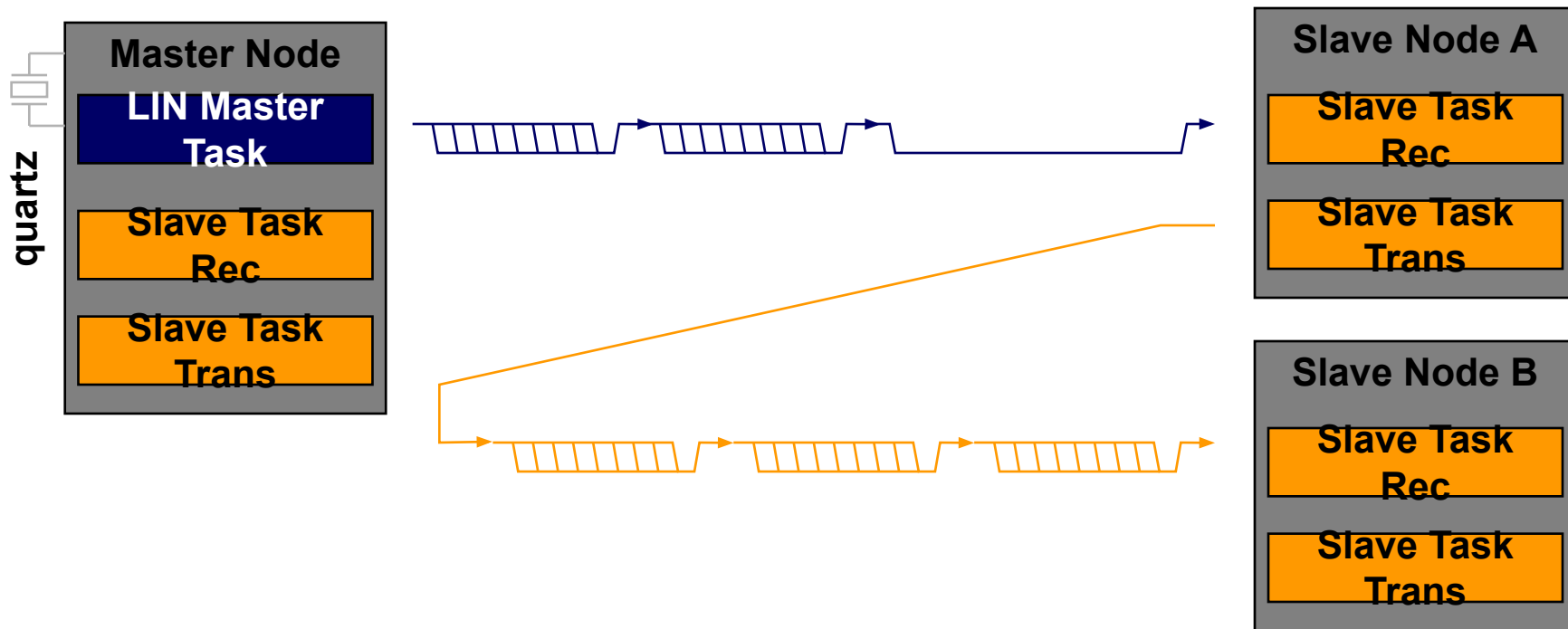
LIN Message Frame
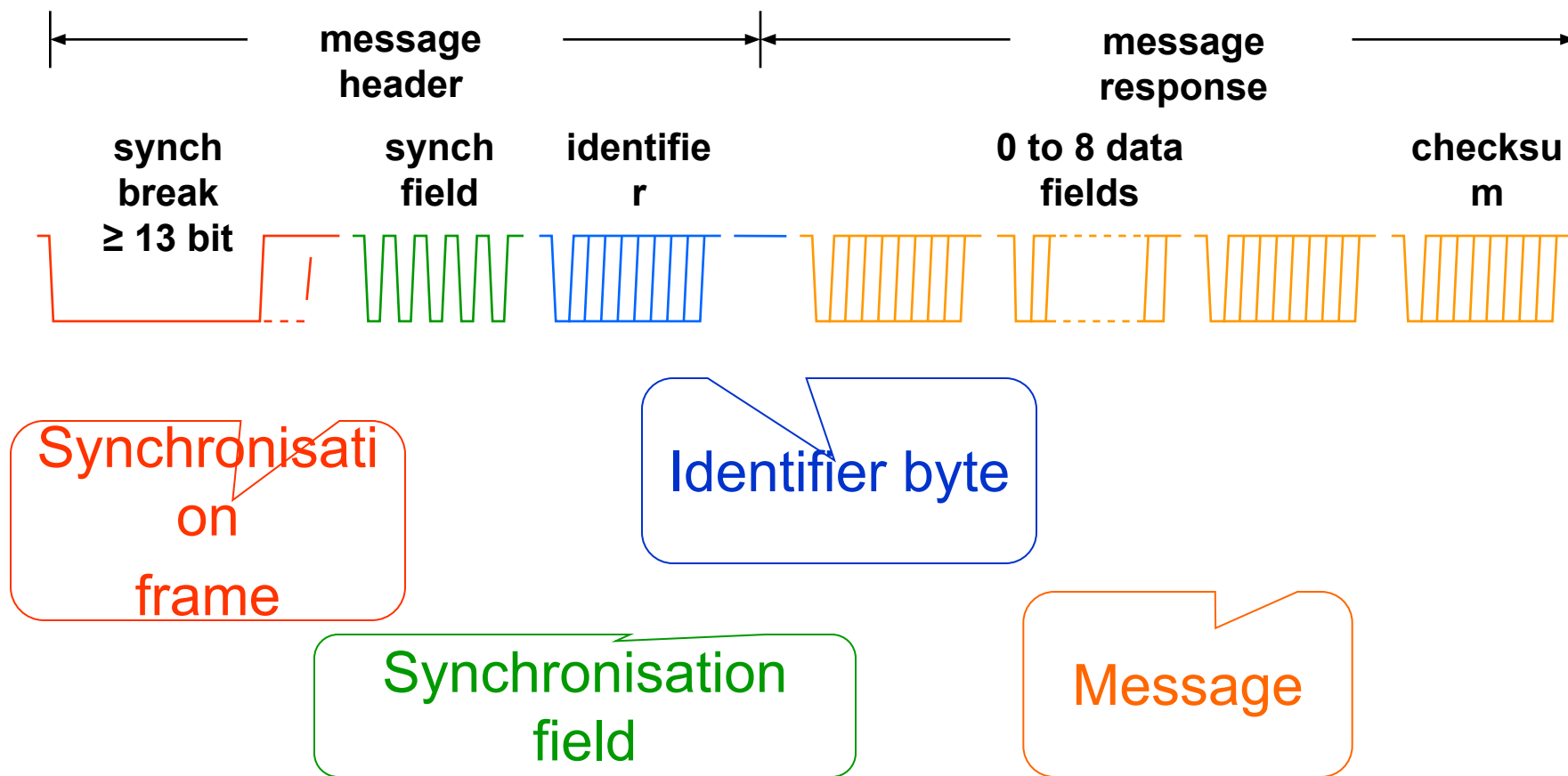
Frame Synchronisation (1)

Initial conditions: +/- 4% baud rate accuracy relative the transmitting source

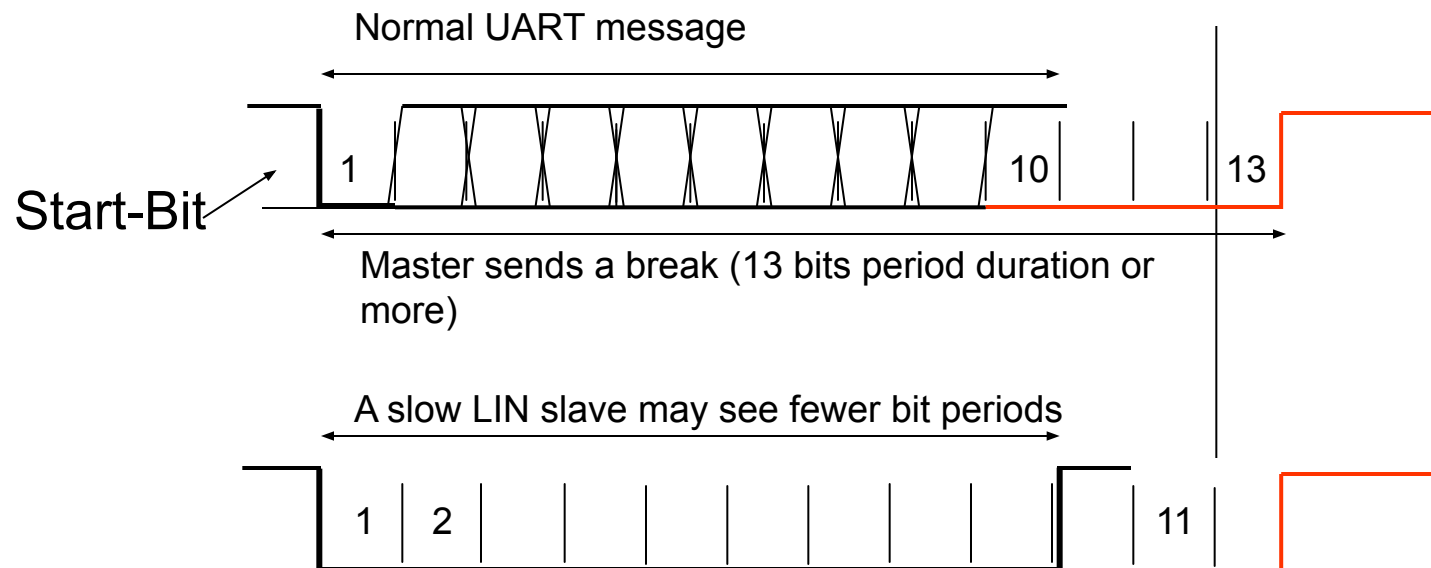A standard transmission of data will require matched send and receiver baud rates

Standard UART byte

Start-Bit

Stop bit
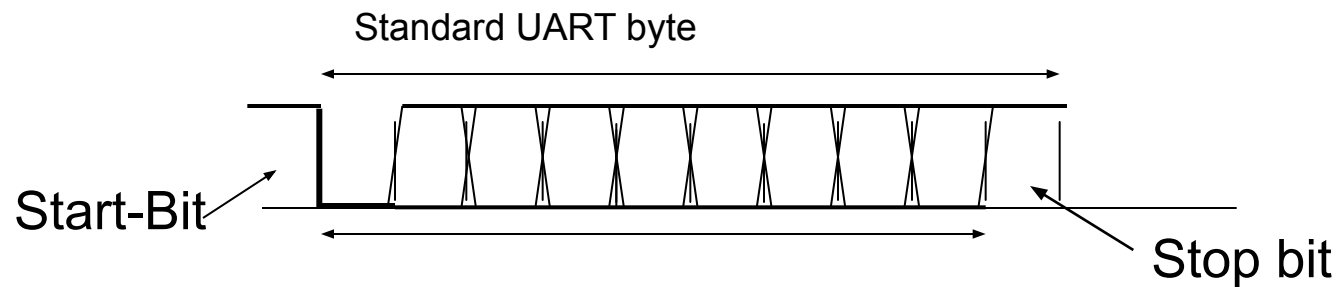
A normal UART with <4% baud rate error will read back the data correctly

MOTOROLA
intelligence everywhere

digital dna
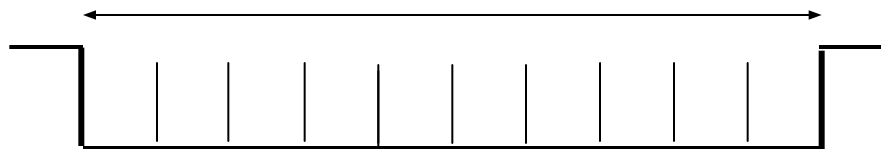
Frame Synchronisation (2)

Initial conditions: +/- 15% baud rate accuracy relative the the LIN master transmitting the synchronisation frame

A synch break must be at least 13 bit periods in duration to allow for this initial variation in oscillator accuracy within the LIN slave


Normal UART message

Start-Bit

1 ... 10 | | 13

Master sends a break (13 bits period duration or more)

A slow LIN slave may see fewer bit periods

1 | 2 | | | | | | | 11

MOTOROLA
intelligence everywhere™

digital dna™

Bit-Synchronisation

- A start bit transition to a low logic level (dominant) indicates a start of a byte, least significiant first and completing with a logic high level (resessive) bit to indicate the STOP bit

Start-Bit   Stop-Bit
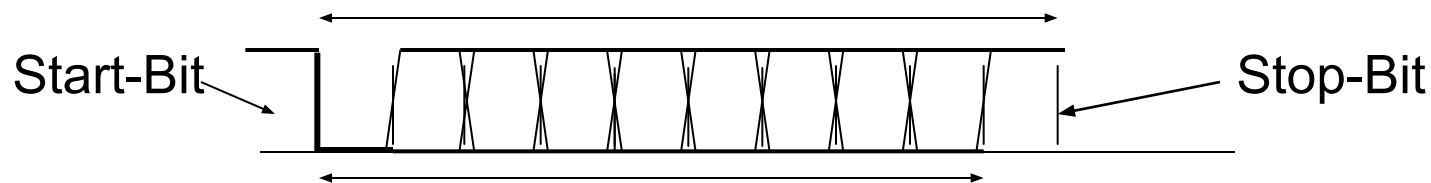
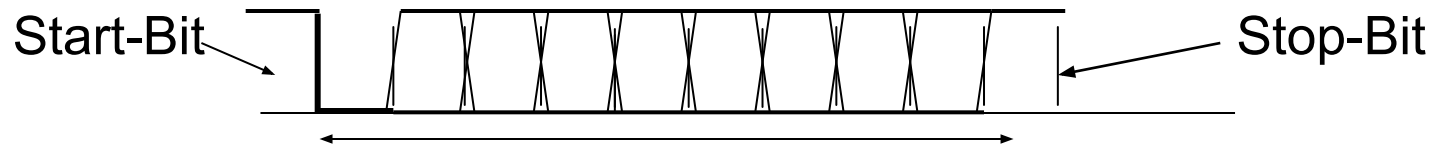## Data is sampled in the middle of the bit field:
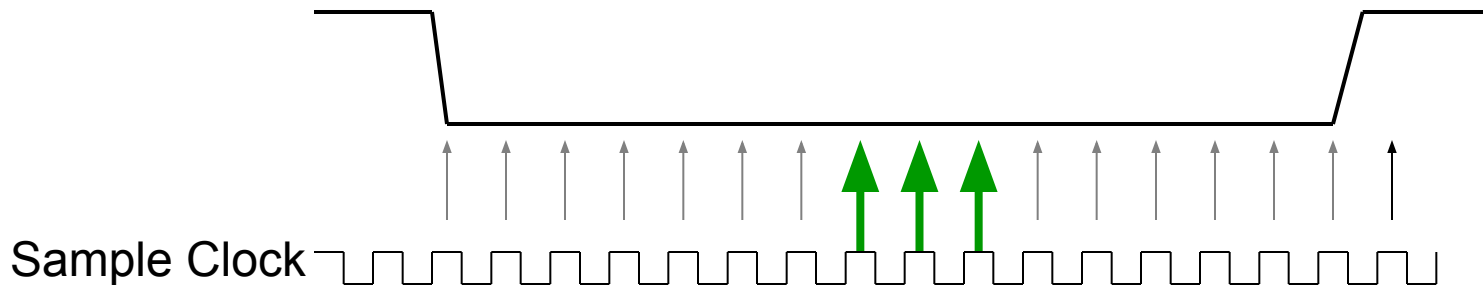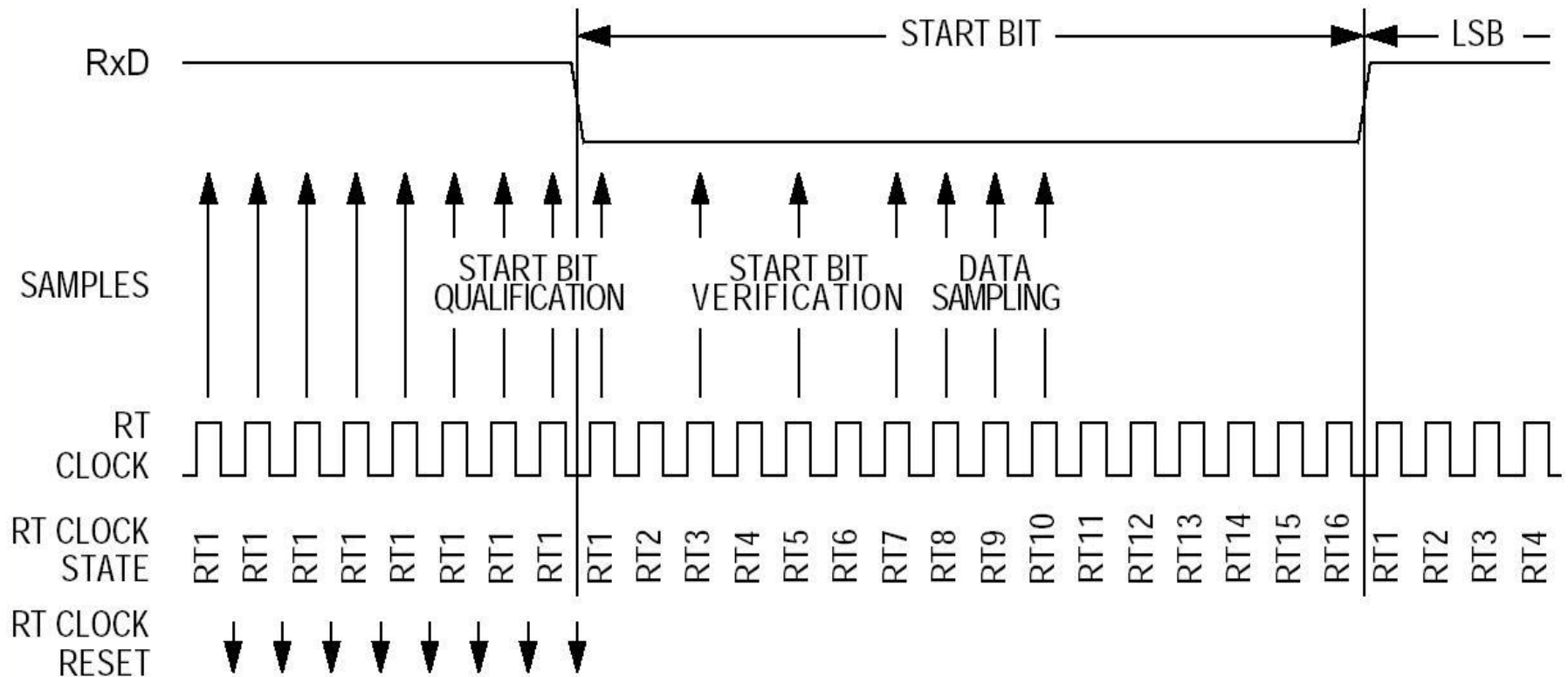
Sample Clock

MOTOROLA intelligence everywhere™

digital dna™

Bit Sampling

MOTOROLA intelligence everywhere

digital dna

Bit-Synchronisation

Start-Bit ———→   ←——— Stop-Bit
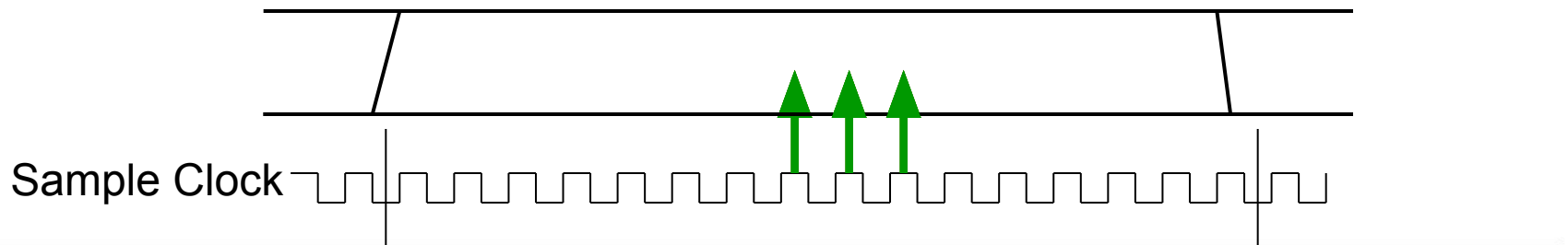
After recognition of a Low level in the start bit, the data is sampled at a rate 16 times the bit rate expected. The middle 3 samples must all agree for an error free reception of the data.

A stop bit is expected after 1 start bit and 8 data bits in a typical message

Sample Clock

MOTOROLA intelligence everywhere™

digital dna™
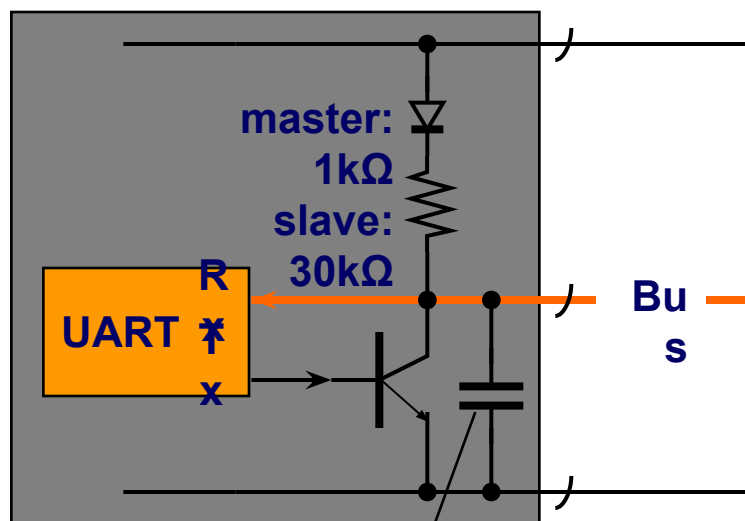
Taking account of Ground-Shift

The detection point for data transitions can be affected by voltage references. Ground shift can change this reference by a significant amount, affecting the bit timing of the data
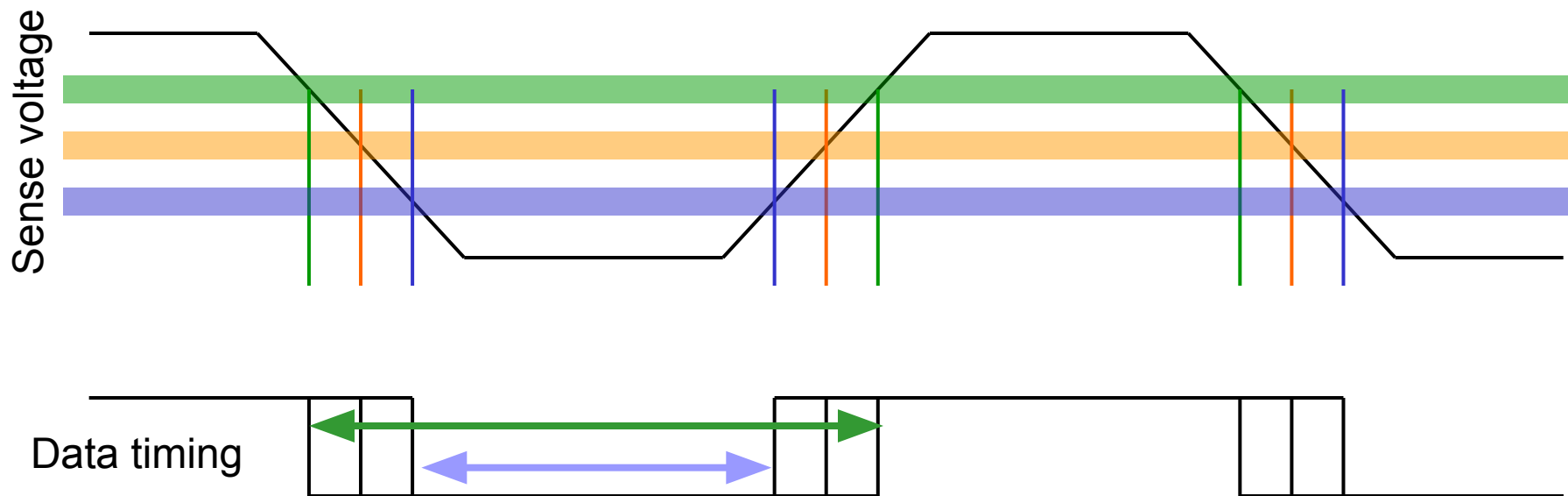
Available bit sampling zone can reduce worst case bit width to around 40us at 20k baud
This affects the overall baud rate tolerance required for safe LIN communications

MOTOROLA intelligence everywhere™

digital dna™

LIN Physical Interface

Electronic Control Unit

Bus Voltage

master:
1kΩ
slave:
30kΩ

UART
R x
T x

Bus

Example capacitances
master: 2.2nF
slave: 220pF

VBAT
8...18 V

60 %

40 %

GND

recessive
logic '1'

controlled
slope
~2V/µs

dominant
logic '0'

Time

Note:
The LIN specification refers to the ECU connector voltages !

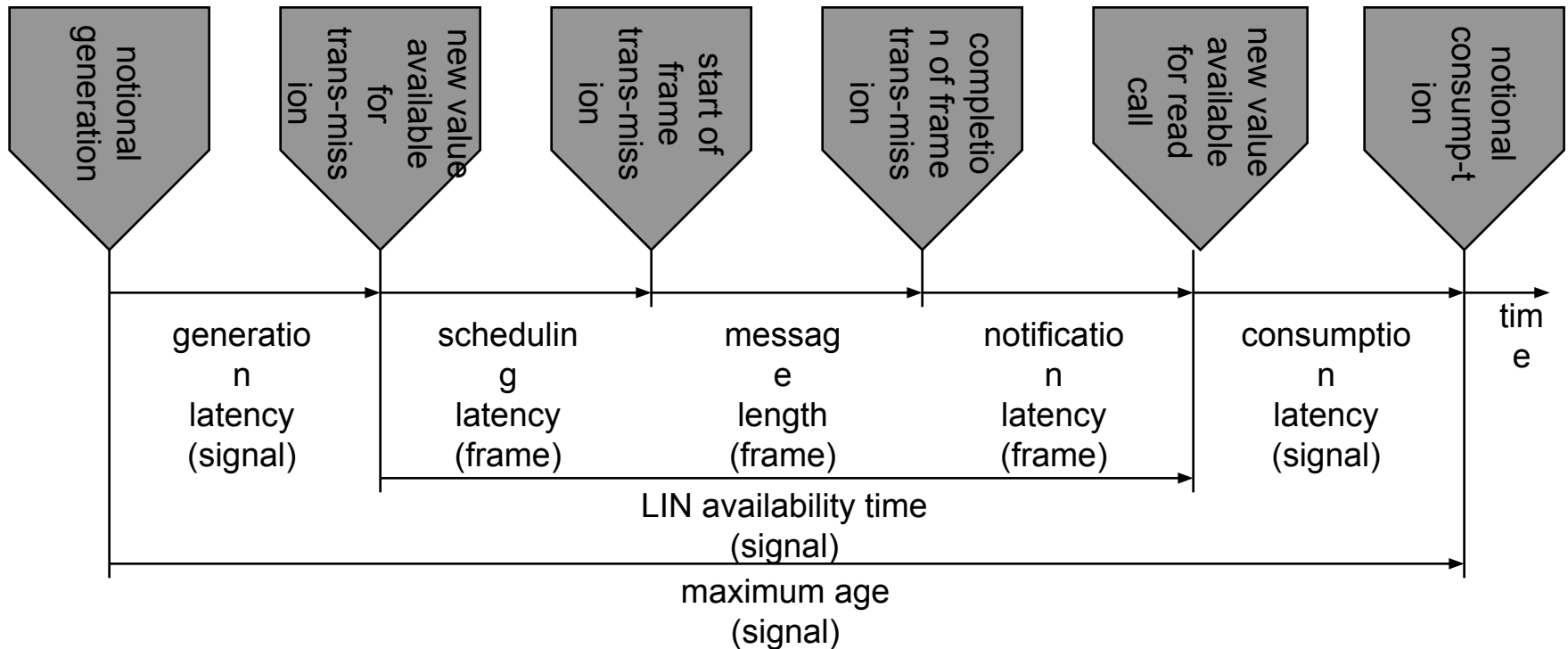**MOTOROLA** intelligence everywhere™

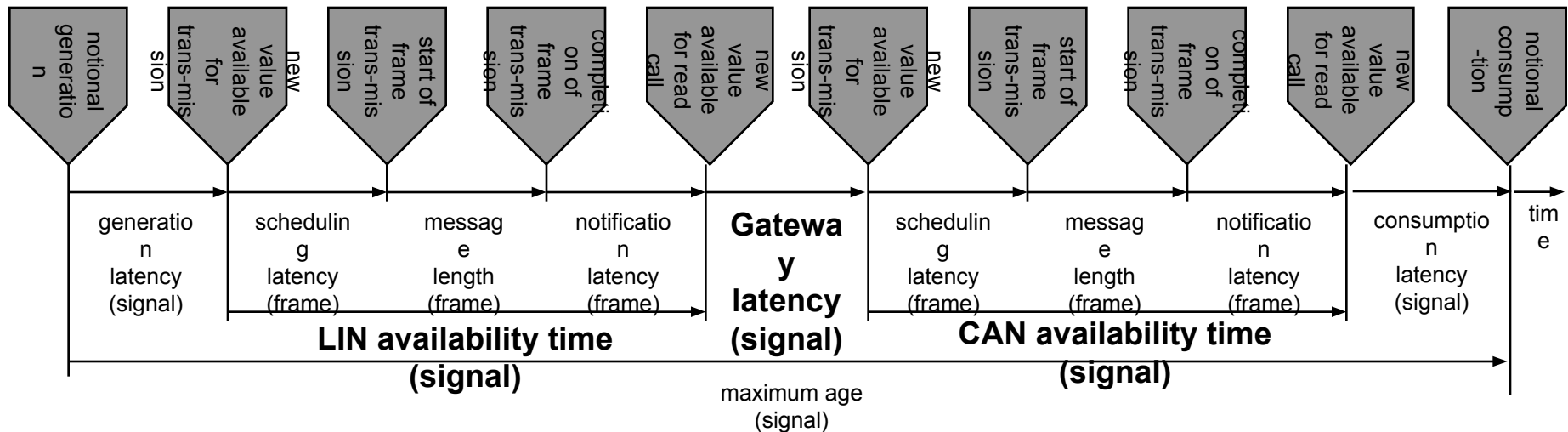digitaldna™
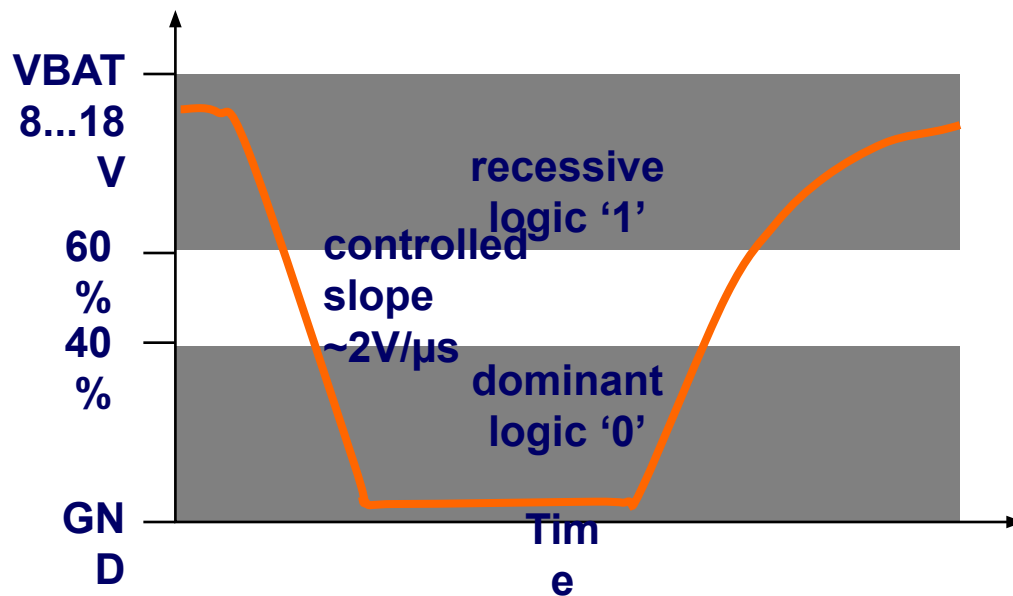
Examination of whether the Deadline is met

- Signal based messaging with static latency analysis ensures that all signals meet defined minimum latency times

- Drives need for complete configuration tool support to ensure guaranteed timing of all signals in a LIN network

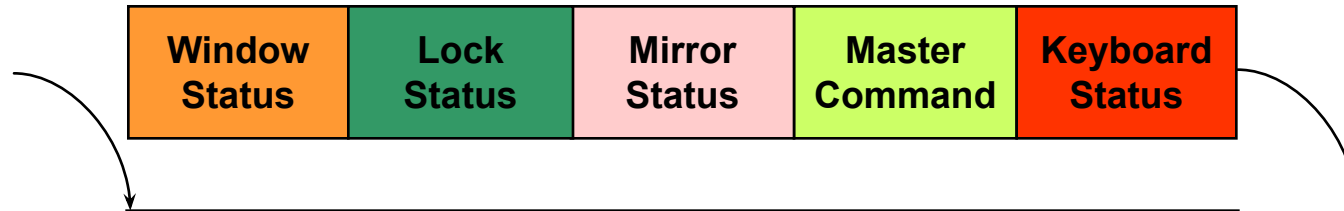**longest observed response time**

deadline

probability

response time

best-case

worst-case

MOTOROLA intelligence everywhere™

digital dna™

Message latency

*
TSPG – 8/16 bit Products Division

MOTOROLA and the Stylized M Logo are registered in the US Patent & Trademark Office. All other
product or service names are the property of their respective owners. © Motorola, Inc. 2001.

MOTOROLA
intelligence everywhere™

digital dna™

Message latency across a network

Latency optimisation with LIN

Basic schedule

Window Status	Lock Status	Mirror Status	Master Command	Keyboard Status

Alternate schedule for low latency signals from a keyboard

Window Status	Keyboard Status	Lock Status	Keyboard Status	Mirror Status	Keyboard Status	Master Command	Keyboard Status

MOTOROLA intelligence everywhere™

digital dna™
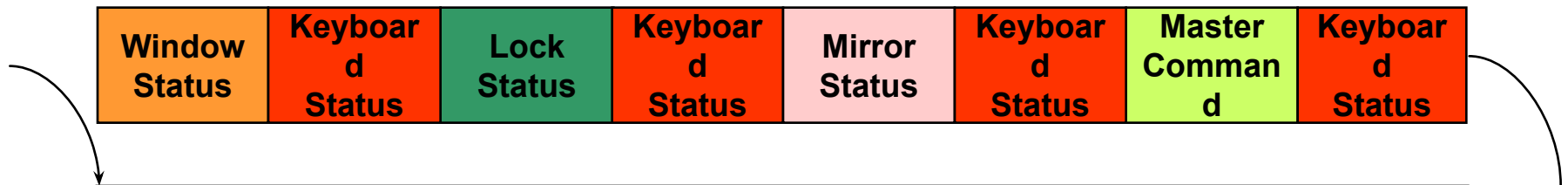
Variables Scheduling
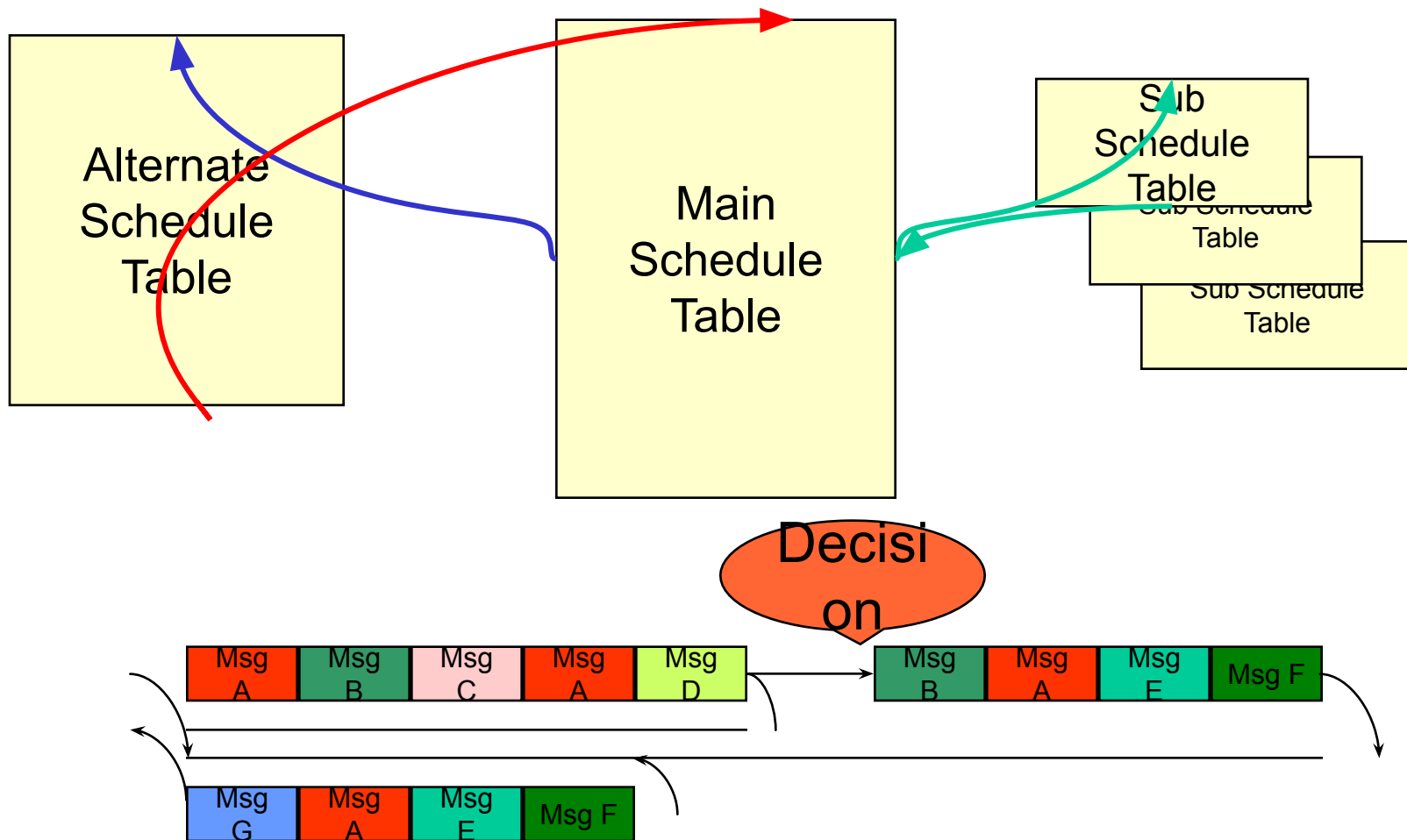
Event Triggered Message

- Problem
  - **Specific node communication required but this takes up too much time for all network messages**
- Solution : Event Triggered frame:
  - **Header is sent out**
    1. **normal case: no answer**
    2. **Rare response: only one node responds**
    3. **Very rare response : several nodes respond simultaneously**
- Cases 1 and 3 are exceptions that should be addressed at the application design.
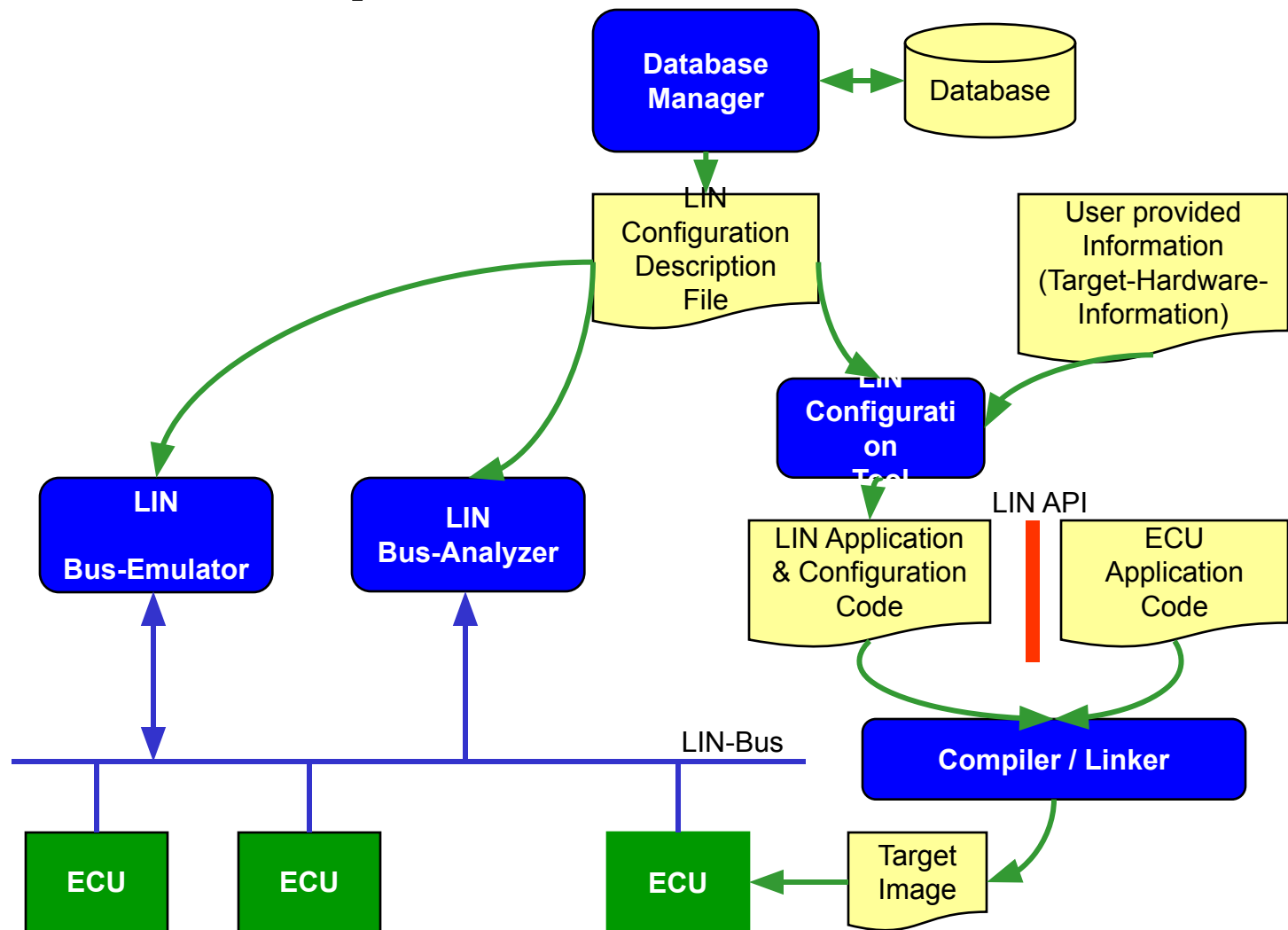- Event triggered messaging is complementary to the regular signal based messaging scheme

MOTOROLA
intelligence *everywhere*™

digital dna™

Further information

 - **Consortium**

http://www.lin-subbus.org

LIN Development Flow

LIN Configuration Description File

- Includes all essential information of network signals, latency periods, cycle times, nodes affected

- Input file serves as a development interface for a node

- LIN Application Generator
  - **LIN-Emulator**
  - **LIN Analyser**

MOTOROLA
intelligence everywhere™

digital dna™

The Workflow

- **Data Input**
    - **Definition of objects**
    - **Definition of relations between the objects**

- **Data Processing**
    - **Signal Packing (Frame Editor/Frame Compiler)**
    - **Timing Analysis**

- **Data Output**
    - **Configuration file generation**
    - **Various optional customer-defined post-operations**

MOTOROLA
intelligence everywhere™

digitaldna™