EE414 Embedded Systems

Ch 7. Network Interface

Part 1/2

Byung Kook Kim
School of Electrical Engineering
Korea Advanced Institute of Science and Technology

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7.1 Advanced Communication Principles

- **Communication among processors**
  - Between computers
  - On-board buses
  - On-chip buses

- **Layering**
  - Hierarchical organization of a communication protocol
  - Lower levels provide services to higher level
    - Lower level might work with bits while
    - higher level might work with packets of data.
  - Break complexity of communication protocol into pieces: easier to design and understand

Advanced Communication Principles (II)

ISO OSI 7 Layer

(International Standardization Organization – Open System Interconnection)

OSI Model			
	Data unit	Layer	Function
Host layers	Data	7. Application	Network process to application
		6. Presentation	Data representation, encryption and decryption, convert machine dependent data to machine independent data
		5. Session	Interhost communication
	Segments	4. Transport	End-to-end connections and reliability, flow control
Media layers	Packet	3. Network	Path determination and logical addressing
	Frame	2. Data Link	Physical addressing
	Bit	1. Physical	Media, signal and binary transmission

Advanced Communication Principles (III)

- Communications (in Physical Layer)
  - A. Parallel communication
    - Physical layer capable of transporting multiple bits of data
  - B. Serial communication
    - Physical layer transports one bit of data at a time
  - C. Wireless communication
    - No physical connection needed for transport at physical layer.

A. Parallel Communication

- Multiple data, control, and possibly power wires
  - One bit data per wire
  - Running in parallel

- Features
  - Typically used when connecting devices on same IC or same circuit board
  - Bus must be kept short
    - Long parallel wires result in high capacitance values which requires more time to charge/discharge
    - Data misalignment between wires increases as length increases

- Adv: High data throughput (with short distances)
- Disadv: Higher cost, bulky.

B. Serial Communication

- Single data wire, possibly also control and power wires
  - Words transmitted one bit at a time

- Adv
  - Higher data throughput with long distances
    - Less average capacitance, so more bits per unit of time
  - Cheaper, less bulky

- Disadv
  - More complex interfacing logic and communication protocol
    - Sender needs to decompose word into bits
    - Receiver needs to recompose bits into word
    - Control signals often sent on same wire as data increasing protocol complexity.

C. Wireless Communication

- Infrared (IR)
  - Electronic wave frequencies just below visible light spectrum
  - IR Diode emits infrared light to generate signal
  - Infrared photo transistor detects signal, conducts when exposed to infrared light
  - Adv: Cheap to build
  - Disadv: Need line of sight, limited range
- Radio frequency (RF)
  - Electromagnetic wave frequencies in radio spectrum
  - Adv: Line of sight not needed, transmitter power determines range
  - Disadv: Analog circuitry and antenna needed on both sides of transmission.

Error Detection and Correction

- Error detection: ability of receiver to detect errors during transmission
- Error correction: ability of receiver and transmitter to cooperate to correct problem
  - Typically done by acknowledgement/retransmission protocol

- Bit error: single bit is inverted
- Burst of bit error: consecutive bits received incorrectly

- Parity: extra bit sent with word used for error detection
  - Odd parity: data word plus parity bit contains odd number of 1's
  - Even parity: data word plus parity bit contains even number of 1's
  - Always detects single bit errors, but not all burst bit errors
- Checksum: extra word sent with data packet of multiple words
  - e.g., extra word contains XOR sum of all data words in packet.

7.2 Parallel Protocols
7.2.1 PCI Bus

- PCI (Peripheral Component Interconnect) Bus
  - High performance bus originated at Intel in the early 1990's
    - 132 MB/s initially.
    - 32-bit transfer at 33 MHz clock
    - Later extended to 64-bit while maintaining compatibility with 32-bit schemes
  - Standard adopted by industry and administered by PCISIG (PCI Special Interest Group)
  - Interconnects chips, expansion boards, processor memory subsystems
  - Synchronous bus architecture
  - Multiplexed data/address lines

7.2.2 ARM Bus

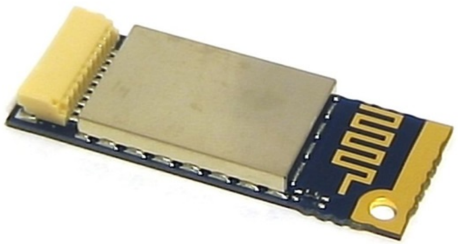
- ARM Bus
  - Designed and used internally by ARM Corporation
  - Interfaces with ARM line of processors
  - 32-bit data, 32-bit addressing
  - Synchronous data transfer architecture
  - Data transfer rate is a function of clock speed
    - If clock speed of bus is X, transfer rate = 16 x X bits/s
    - 32 x X bits/s possible.

7.3 Wireless Protocols
7.3.1 IrDA

- IrDA (Infrared Data Association)
  - Protocol suite that supports short-range point-to-point infrared data transmission
  - Created and promoted by the Infrared Data Association (IrDA)
  - Data transfer rate of 9.6 kbps and 4 Mbps
  - IrDA hardware deployed in notebook computers, printers, PDAs, digital cameras, public phones, cell phones
  - Lack of suitable drivers has slowed use by applications
  - Windows 7/10 now include support
  - Becoming available on popular embedded OS's
  - Adv: Simplicity and low cost of IrDA hardware.
  - Disadv: Line of sight.

7.3.2 Bluetooth

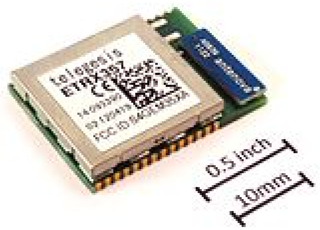
- Bluetooth
  - New, global standard for wireless connectivity
    - Ericcson 1994 – Wireless alternative to RS-232C
    - Standard: IEEE 802.15.1
  - Based on low-cost, short-range radio link
    - ISM (Industrial, Scientific, and Medical) radio bands - 2.4 to 2.485 GHz
  - Connection established when within 10 meters (or 100 meters) of each other
  - No line-of-sight required
    - e.g., Connect to printer in another room



Bluetooth (II) [Wikipedia]

- Implementation
  - 79 Bluetooth channels with 1 MHz bandwidth
  - Bluetooth low energy: 40 channels with 2 MHz bandwidth
  - Data rage: 1, 2, or 3 Mbps
  - Packet based protocol with a master-slave structure.
- Specifications
  - Bluetooth 1.0/1.1/1.2 Inter-operable
  - 2.0/2.1: Enhanced Data Rate up to 3 Mbps (2004)
  - 3.0: High speed 24 Mbps (2009)
  - 4.0/4.1/4.2: Bluetooth Low Energy protocol (2010)
  - 5.0: IoT (2016/17)
- Applications
  - Keyboard, Mouse, Earphone

7.3.3 Zigbee [Wikipedia]



- An IEEE 802.15.4-based specification for a suite of high-level communication protocols used to create personal area networks with small, low-power digital radios.
- Simpler and less expensive than other wireless personal area networks (WPANs), such as Bluetooth or Wi-Fi.
- Transmission distances to 10–100 meters line-of-sight,
- Can transmit data over long distances by passing data through a mesh network of intermediate devices to reach more distant ones.
- Data rate of 250 kbit/s, best suited for intermittent data transmissions from a sensor or input device.

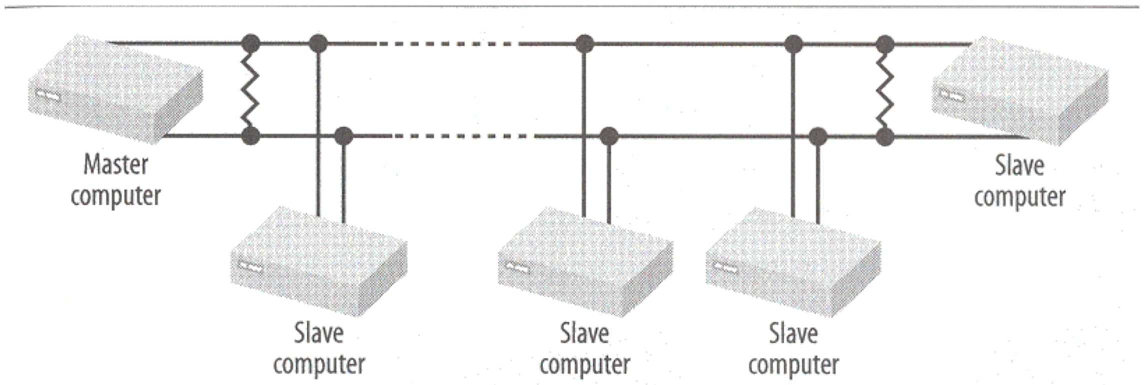
7.3.4 IEEE 802.11 WLAN

- IEEE 802.11
  - Proposed standard for wireless LANs
  - Specifies parameters for PHY and MAC layers of network
    - PHY layer
      - physical layer
      - handles transmission of data between nodes
      - provisions for data transfer rates of 1 to 54 Mbps, or 108 Mbps
      - operates in 2.4 to 2.4835 GHz frequency band (RF)
      - or 300 to 428,000 GHz (IR)
    - MAC layer (in Data Link Layer)
      - medium access control layer
      - protocol responsible for maintaining order in shared medium
      - CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance).

7.4 Serial Protocols
RS-485

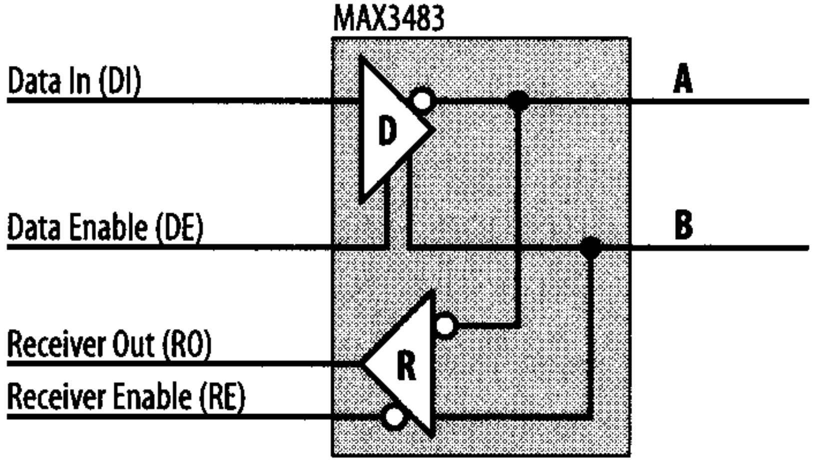
- Features
  - A variation on RS-422
  - Used for low-cost networking up to 10 Mbps.
  - Commonly used in many industrial applications
  - One of the simplest and easiest network to implement.

- RS-485 network
  - Multiple systems (nodes) to exchange data over
    a single twisted pair ->



RS-485 (II)

- Architecture
  - Master/slave architecture
    - All transactions are initiated by the master
    - A slave will transmit only when specifically instructed to do so.
  - No Standard protocols
    - Many different protocols run over RS-485.
    - Can create own protocol specific to the application at hand.
  - RS-485 transceiver →
    - RS-422 transceiver with enable inputs



RS-485 (III)

- Operation
  - All systems connected to the RS-485 network have their receivers enabled and *listen to the traffic*.
  - Only when a system wishes to transmit does it enable its driver.
  - A number of formal protocols use RS-485 as a transmission medium.
- Caution
  - *AVOID* the possibility of *two* nodes on the network *transmitting at the same time.*
  - Designate one node as a master node and the others as slaves.
  - Only the master may initiate a transmission on the network.
  - A slave may respond directly only to the master, once that master has finished.
- Number of nodes on the network
  - 32 normal (512 with some chips).

7.5 CAN (Controller Area Network)

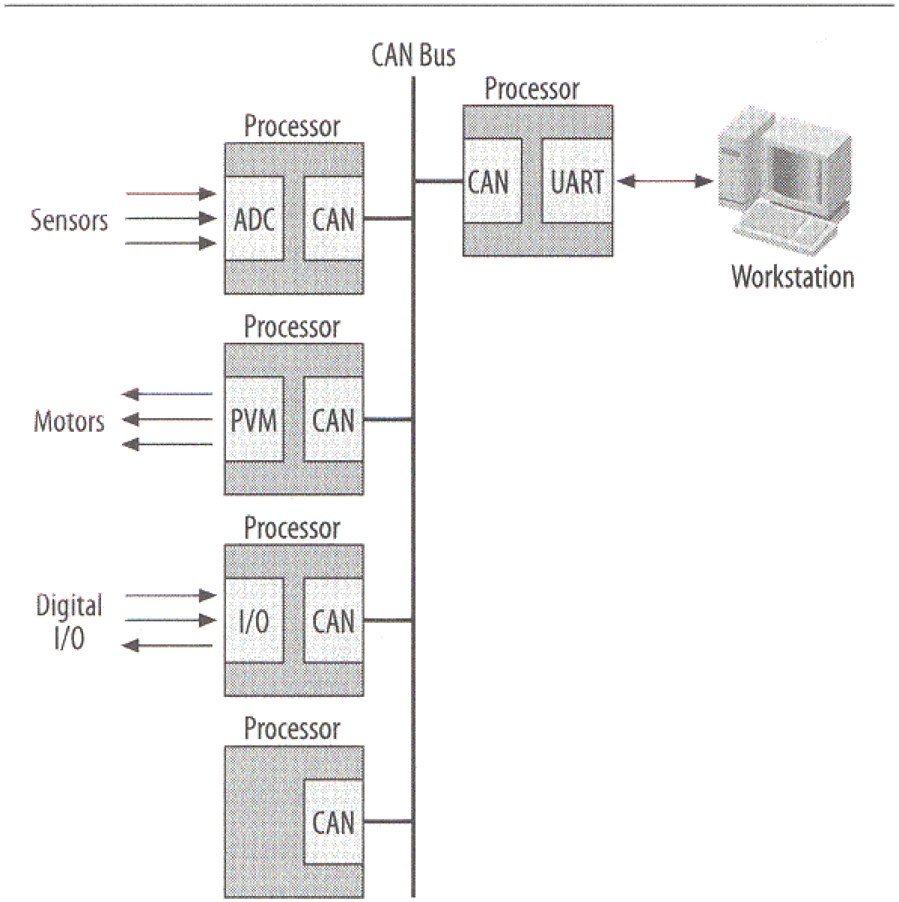
- **CAN (Controller area network)**
  - Protocol for real-time applications developed by Robert Bosch GmbH in late 1980s
  - Originally for communication among components of cars
- Complexity of automotive electronics
  - A considerable amount of information exchange is required.
    - Engine management systems, ABS braking, active suspension, electronic transmission, automated lighting, air-conditioning, security, and central locking
  - Each is part of an integrated whole.
    - Point-pt-point wiring inadequate:
      - wiring/connector cost
      - Unnecessary weight, reduced reliability, servicing a nightmare.
  - Intersystem communication using a low-cost digital network.
    - High noise immunity required: 400V transients.

Controller Area Network (II)

- Solution: Controller Area Network (CAN)
  - A real-time communication up to 1 Mbps over a two-wire serial network up to 40 m.
  - Specifies only the physical and data-link layers of the ISO-OSI model.
    - International standard under ISO11898 and ISO11519-2.

- Robustness
  - Expanded beyond automotive
  - Industrial automation, trains, ship navigation and control systems
  - Medical systems, photocopiers, agricultural machinery, household appliances, office automation, and elevators.

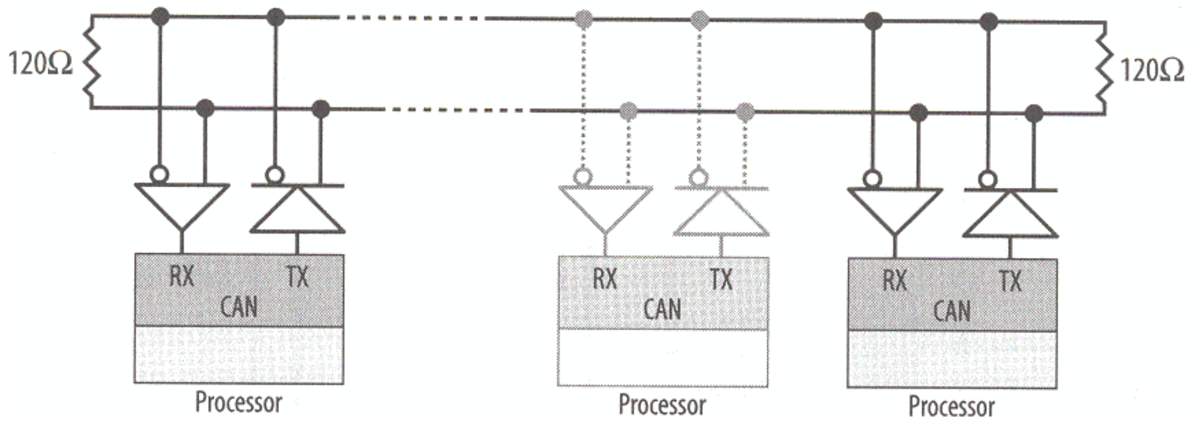
CAN (III)



- CAN distributed system
  - Supports multiple masters on the network
  - Each master responsible for local sensing and control within the distributed system →
  - CAN packet
    - Contains address information and priority as part of the header
  - The nodes may connect to and disconnect from the network, without affecting network traffic between other nodes.

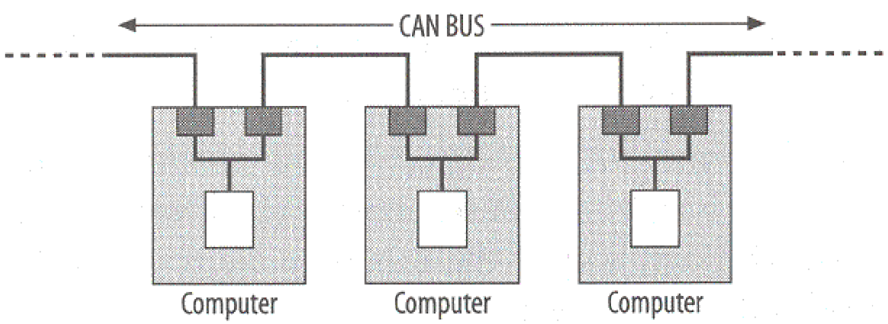
CAN (IV)

- CAN network
  - Wired-AND logic
  - Maximum bus-length of
    - 1000 meters (3300 feet) at 10 kbps
    - 40 meters (133 feet) at 1 Mbps
  - Termination
    - Each end of the bus requires termination resistors (120 ohm) to prevent transmission reflections ->

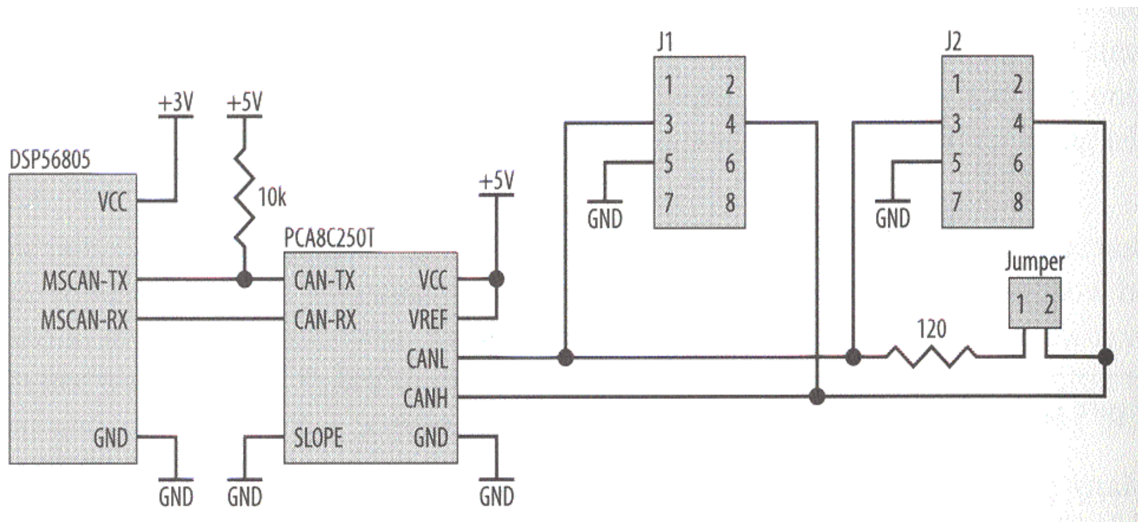


CAN (V)

- CAN module
  - Contained in
    - Many Philips microcontrollers, Few PIC uCs, DSP56805
  - Microchip MCP25120
    - CAN module with SPI host interface



- CAN driver
  - Philips PCA82C250T
- Physical attachment:

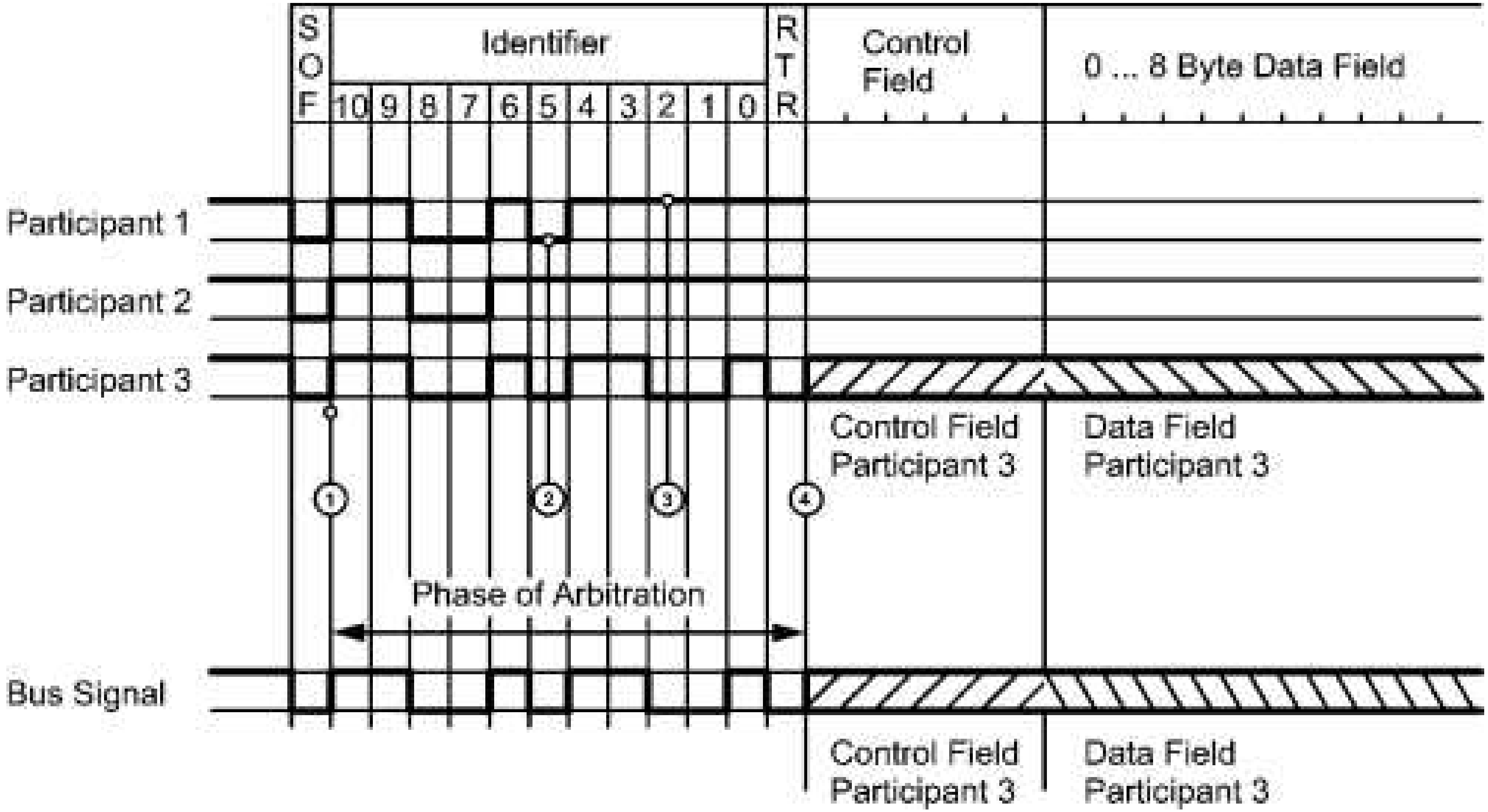


7.6 CAN Protocol

- **Strategy: CSMA/CD+AMP** *(Carrier Sense Multiple Access/Collision Detection with Arbitration on Message Priority).*
  - *Multimaster network.*
  - *The content of the message is labeled by an identifier (11 or 29 bit) that is unique throughout the network.*
- **Non-destructive contention-based bus arbitration**
  - *All nodes are allowed to start the transmission of a frame after the bus is idle.*
  - More than one node are starting transmission at the same time.
  - Each node monitors the bus during transmission of the *identifier field* and the *RTR bit.*
  - As soon as it detects a dominant bit while transmitting a recessive bit it releases the bus, immediately stops transmission and continues receiving the frame.

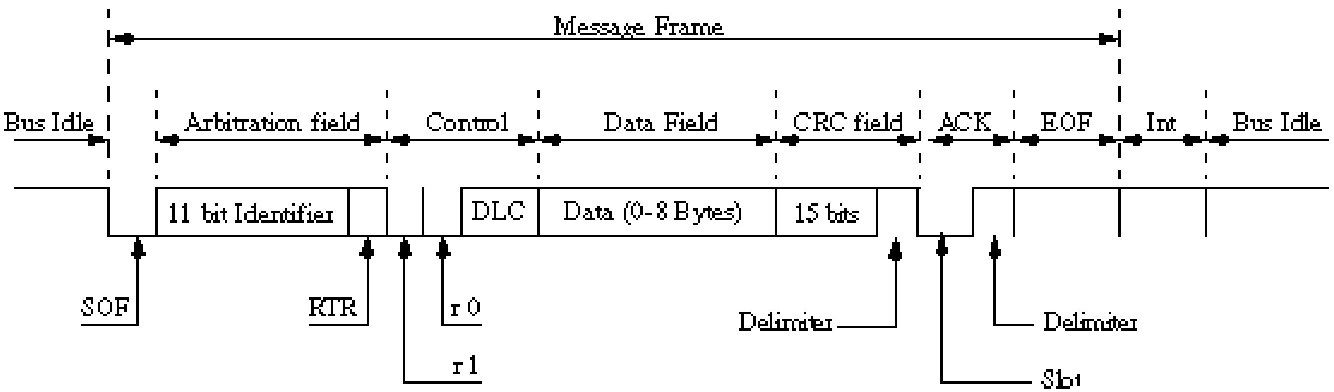
CAN Protocol (II)

- **CAN protocol**

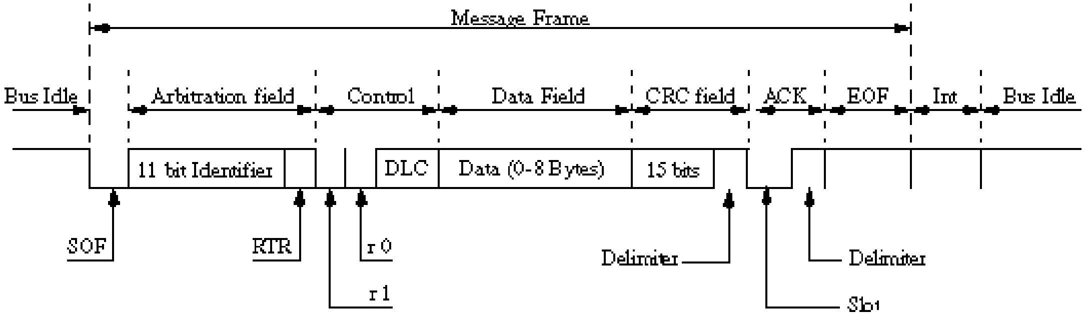


CAN Protocol (III)

- **The format of a standard CAN 2.0A message:**
  - 1. A Start of Frame (SOF) field. This is a dominant (logic 0) bit that indicates the beginning of a message frame.
  - 2. An Arbitration field:
    - An 11 bit message identifier
    - The Remote Transmission Request (RTR) bit.
      - 0: Data Frame.
      - 1: Remote Transmission Request (otherwise known as Remote Frame).
      - A Remote Frame is a request by one node for data from some other node on the bus. Remote Frames do not contain a Data Field.



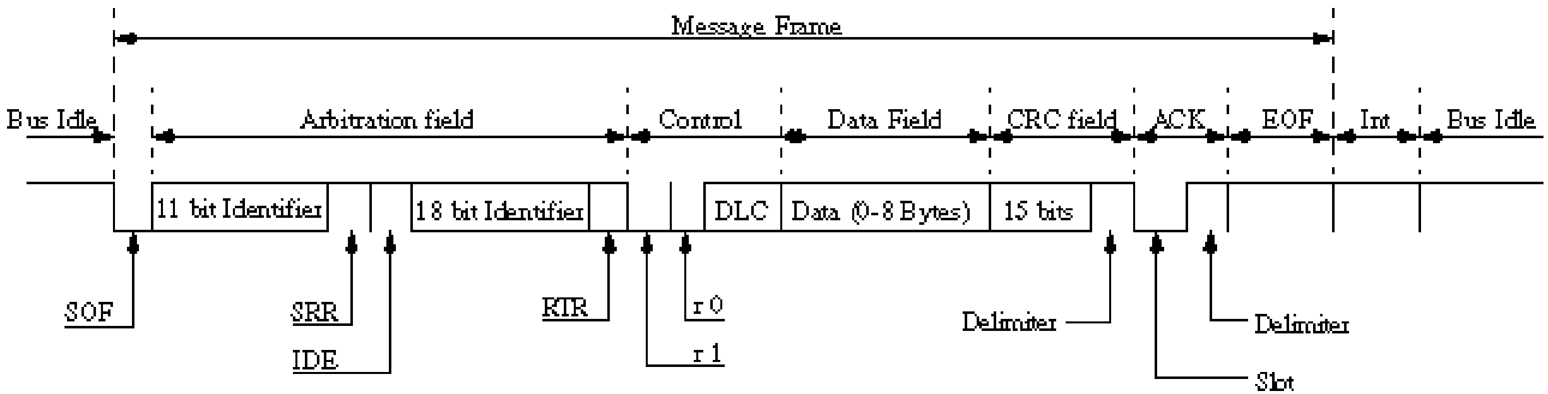
CAN Protocol (IV)



- **The format of a standard CAN 2.0A message (II)**
  - *3. A Control Field* containing six bits:
    - Two dominant bits (r0 and r1) that are reserved for future use, and
    - *A four bit Data Length Code (DLC)* indicates the number of bytes in the Data Field that follows
  - *4. A Data Field*, containing from zero to eight bytes.
  - *5. The CRC field*, containing a *15 bit cyclic redundancy check code* and a recessive delimiter bit
  - 6. The ACKnowledge field, consisting of two bits.
    - The first is the Slot bit which is transmitted as a recessive bit, but is subsequently over written by dominant bits transmitted from all other nodes that successfully receive the message.
    - The second bit is a recessive delimiter bit.
  - *7. The End of Frame field*, consisting of seven recessive bits.
  - *8. The INTermission field* consisting of three recessive bits.
    - After the three bit INTermission period the bus is recognized to be free.
  - *Bus Idle time* may be of any arbitrary length including zero.

CAN Protocol (V)

- **The CAN 2.0B format**
  - In Version 2.0B the Arbitration field contains two identifier bit fields.
    - The first (the base ID) is eleven (11) bits long for compatibility with Version 2.0A.
    - The second field (the ID extension) is eighteen (18) bits long, to give a total length of twenty nine (29) bits.
    - The distinction between the two formats is made using an Identifier Extension (IDE) bit.
  - A Substitute Remote Request (SRR) bit is included in the Arbitration Field.
    - The SRR bit is always transmitted as a recessive bit: Ensure that, in the case of arbitration between a Standard Data Frame and an Extended Data Frame, the Standard Data Frame will always have priority if both messages have the same base (11 bit) identifier.



CAN Protocol (VI)

- **Sophisticated error detection and error confinement mechanisms**
  - Very *sophisticated* error detection and error confinement mechanisms: resulting in a low residual probability of not detected errors.
  - *Monitoring of the transmitted bit level by the transmitting node.*
    - If the monitored bit level is different from the bit level that is sent, a bit error is detected.
    - With this mechanism all globally effective bus errors are detected.
  - Checking of *fixed format elements* and by checking of the *CRC* segment through a receiver.
    - Providing a means for detecting of only locally effective errors with a very high probability.

CAN Protocol (VII)

- **Error signaling instead of message confirmation provides system-wide data consistency and low error recovery times**
  - Only a corrupted message is signaled by means of an error frame.
  - An error frame is transmitted as soon as an error condition is detected by a transmitting or receiving node: The transmitted message is destroyed and so network-wide data consistency provided.
  - If a transmitting node sends or receives an error frame it automatically starts retransmission of the corrupted message: Provides a very short error recovery time which is much lower than that of competing protocols.
  - Counter for counting of transmission and receiving errors and for performing a sophisticated error management.

References

- [1] Frank Vahid, “Embedded system design: A unified hardware/software introduction”, John Wiley & Sons, 2002.
- CAN: Search Internet.