

# Real-Time Embedded Systems

## CpE-450 Spring 06

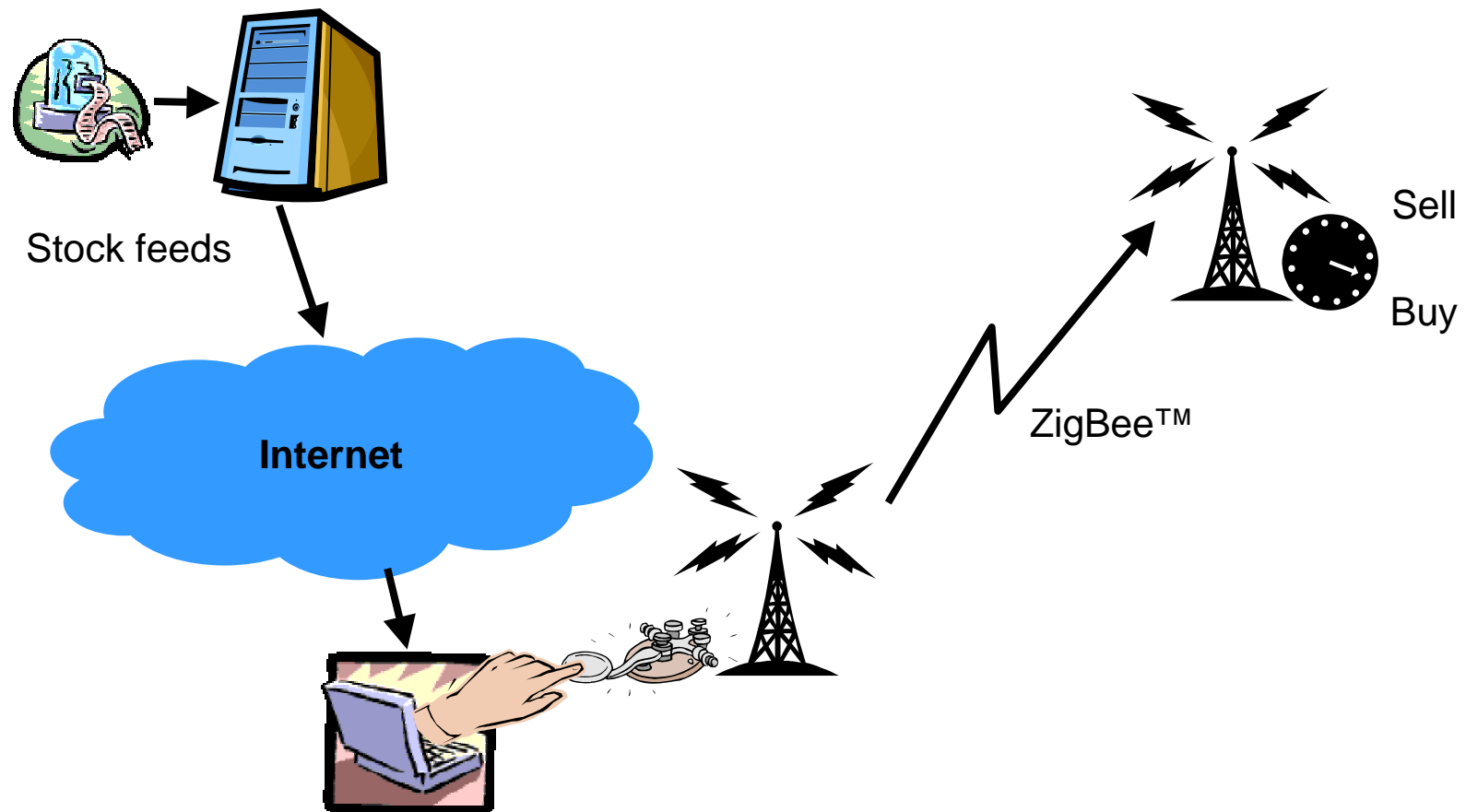
Class 10

Bruce McNair

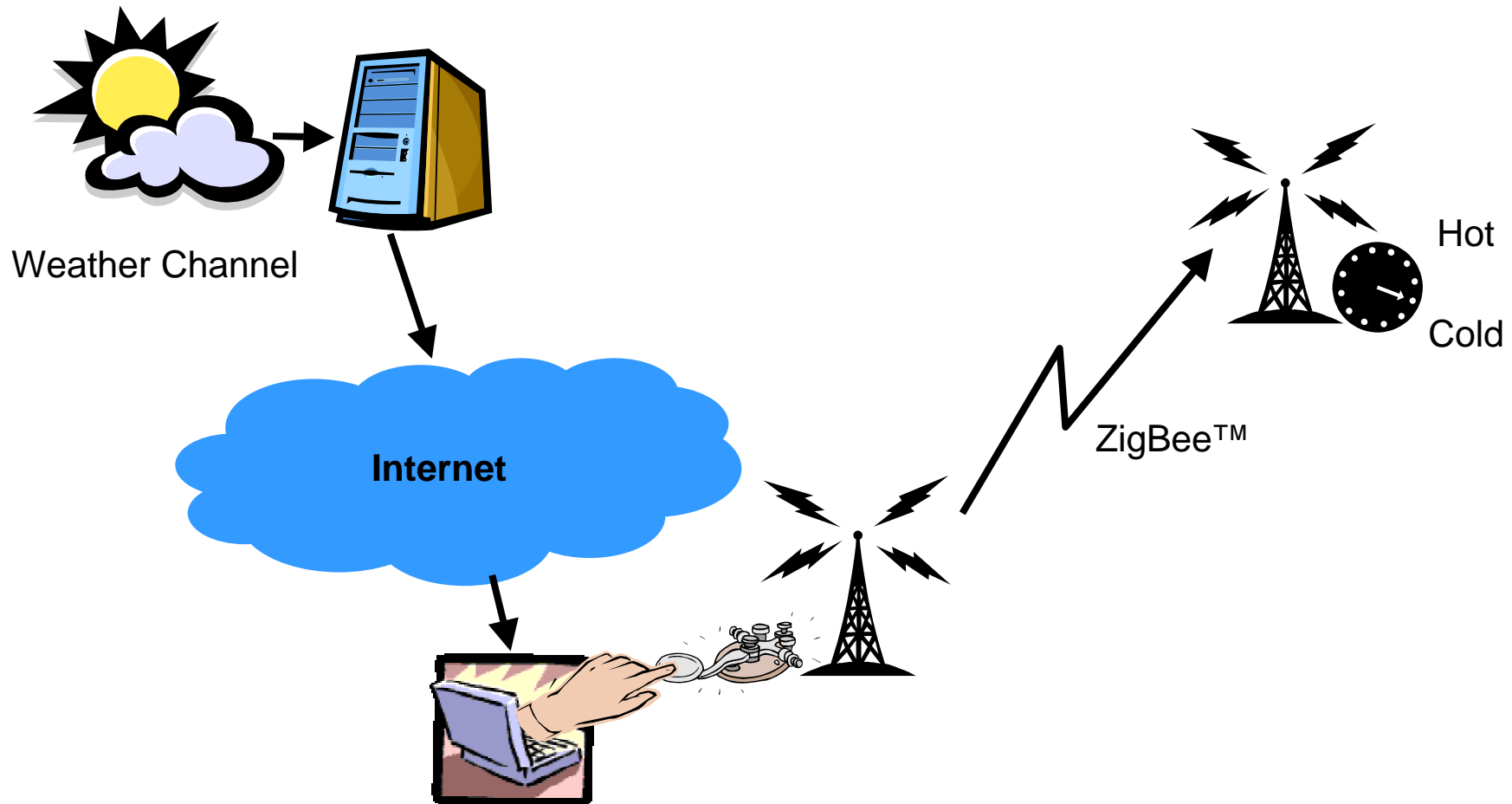
[bmcnair@stevens.edu](mailto:bmcnair@stevens.edu)

# Case Study 1: Real-Time Stimulus for the Day Trader

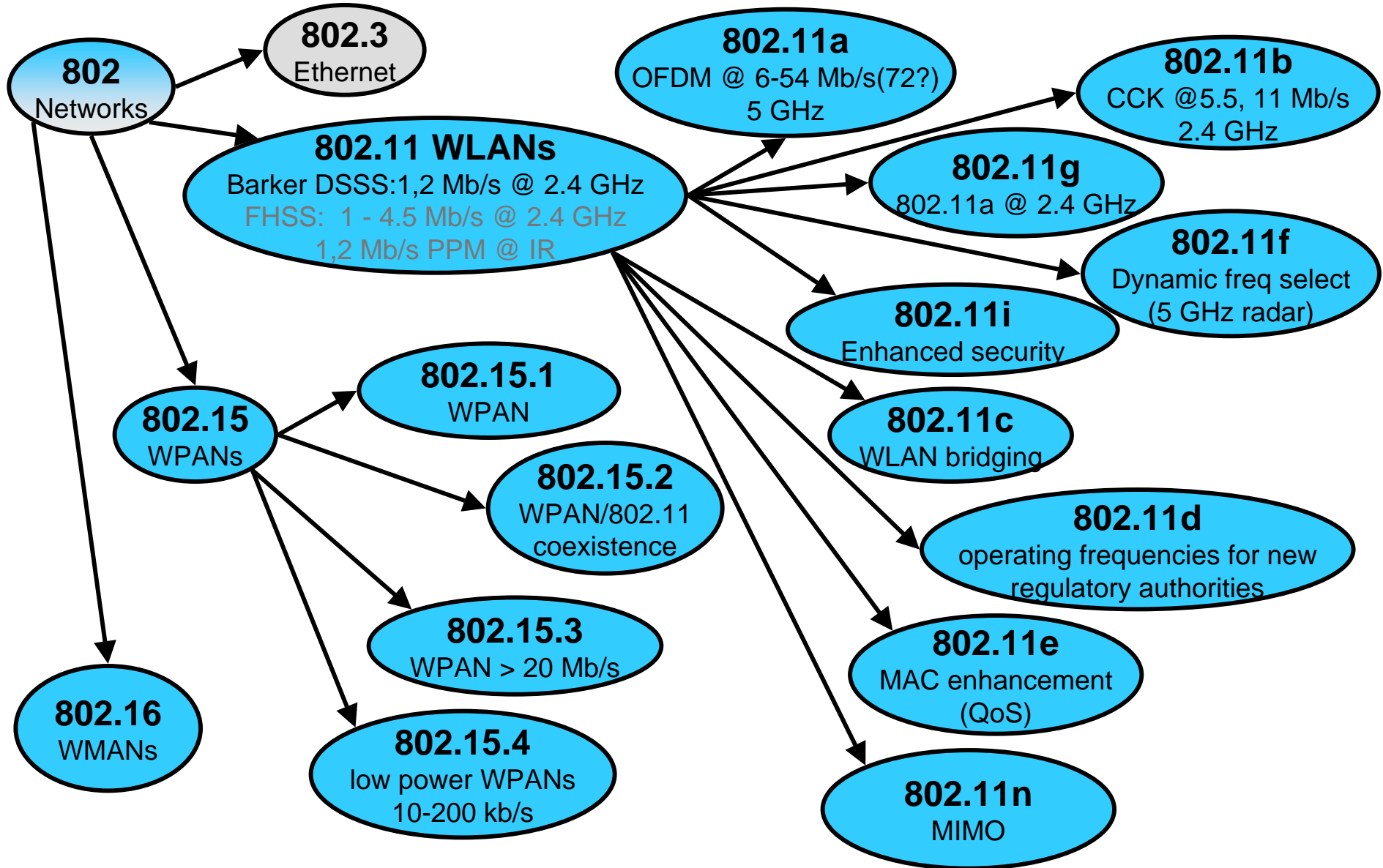
- Richard Hoptroff, "Stock Clock," Circuit Cellar Magazine, April 2006, pp. 58-61.
- [ftp://ftp.circuitcellar.com/pub/Circuit\\_Cellar/2006/189/Hoftroff-189.zip](ftp://ftp.circuitcellar.com/pub/Circuit_Cellar/2006/189/Hoftroff-189.zip)



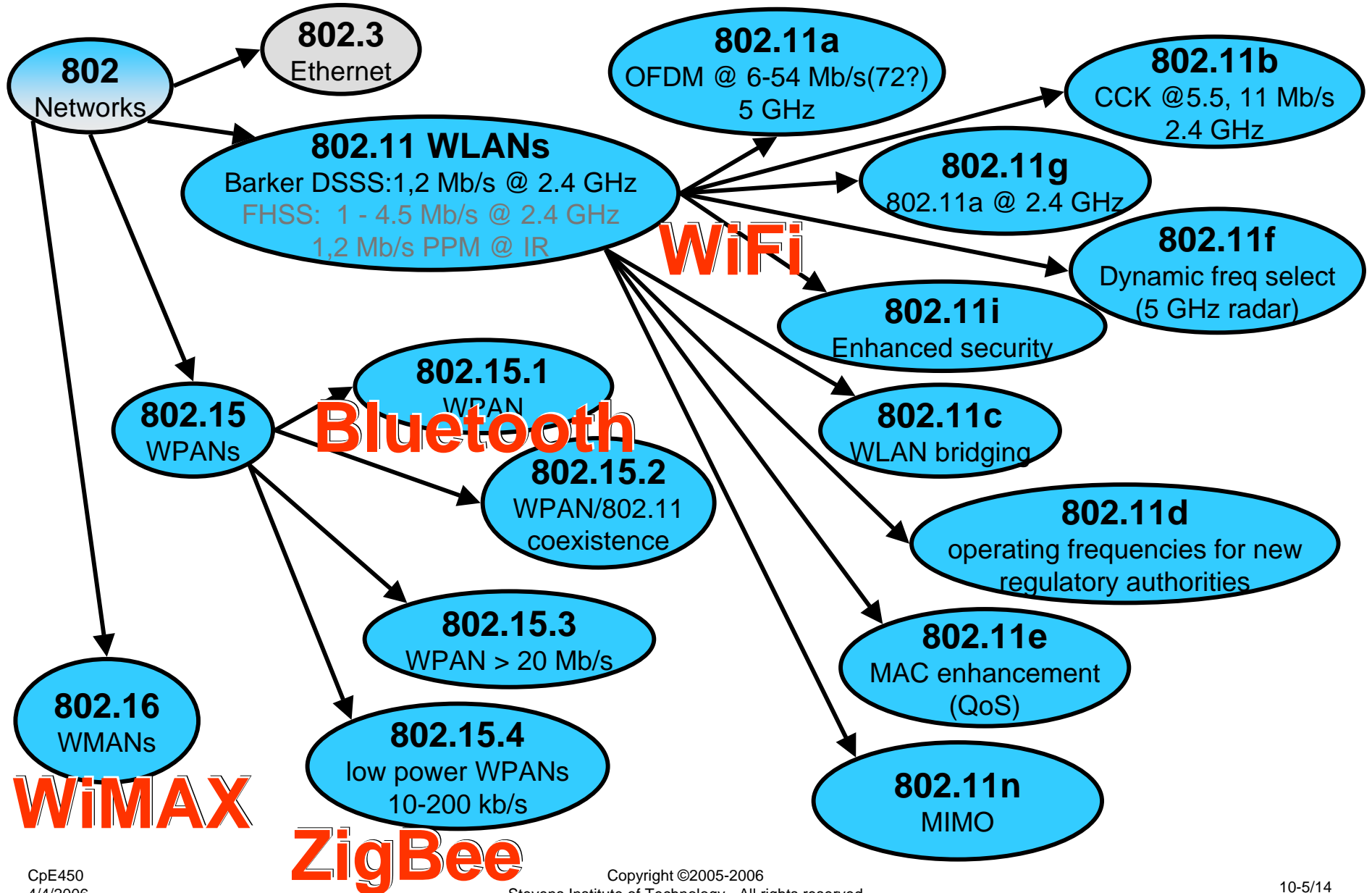
# Case Study 1: Pick your own data source/display



# IEEE 802 Standards (Alphabet Soup)

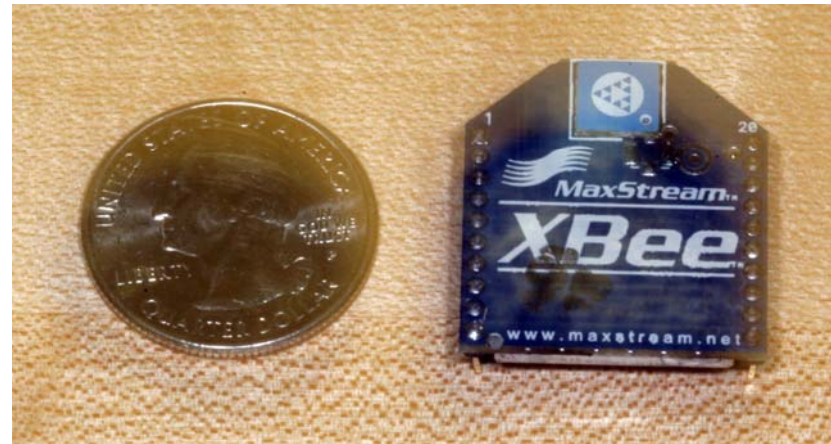


# IEEE 802 Standards (Alphabet Soup)

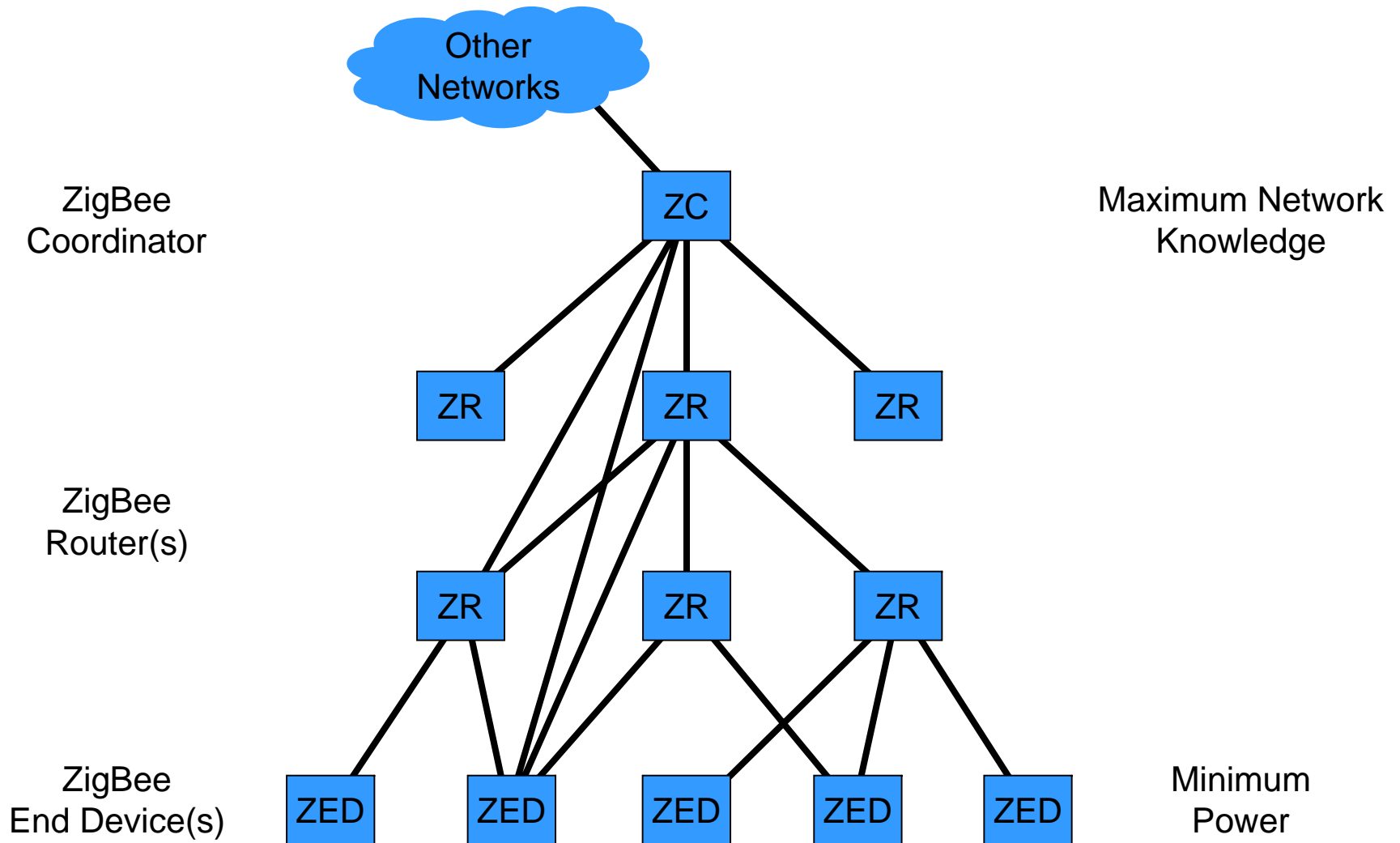


# ZigBee Devices

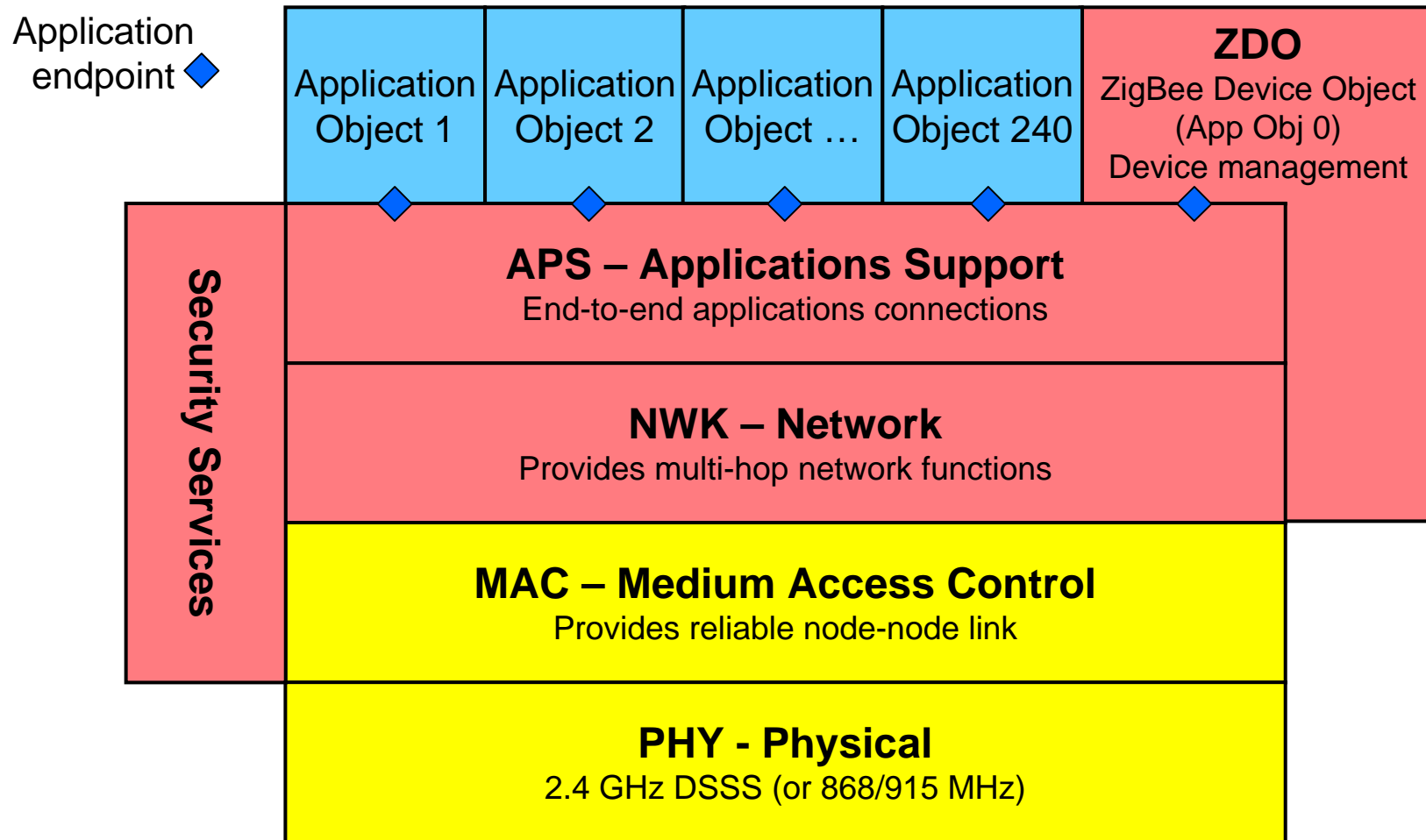
- Transmit power: 1 – 60 mW
- 2.400 – 2.4835 GHz operation
- Channel data rate: 250 kb/s
- End user data rate: 115.2 kb/s
- Direct Sequence Spread Spectrum
- Peer-to-peer, point-to-point, point-to-multipoint and mesh networks
- CSMA-CD
- 12-16 DSSS channels
- 65,000 network addresses per code
- Power-down current  $<10 \mu\text{A}$ , operating current  $\sim 45 \text{ mA}$



# ZigBee Networking



# ZigBee Protocol Stack



Defined by:

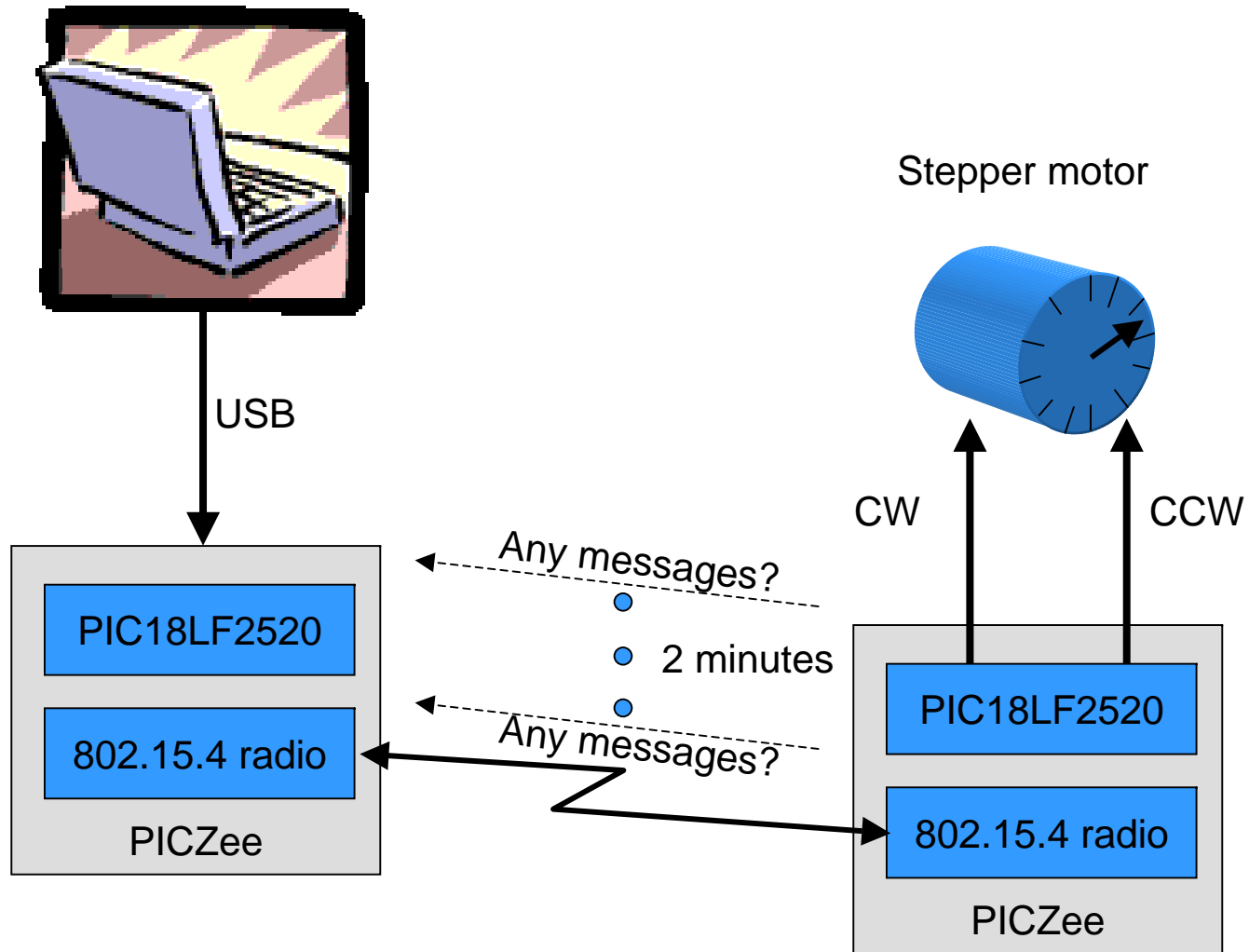
IEEE 802.15.4

ZigBee Alliance

Application developer

Source:  
Pixie™ brochure

# System Components



# Coordinator Code Structure

```
void main(void)
{
    currentPrimitive = NO_PRIMITIVE;
    NetworkDescriptor = NULL;
    ZigBeeInit();
    if(!blsBound) myStatusFlags.bBidSwitchToggled = TRUE;
    while(TRUE)
    {
        ZigBeeTasks( &currentPrimitive );
        switch(currentPrimitive)
        {
            case NLME_NETWORK_FORMATION_confirm:
                process_network_formation(); break;
            case NLME_PERMIT_JOINING_confirm:
                process_network_joining(); break;
            case APSDE_DATA_indication:
                process_binding(); break;
            case APDSE_DATA_confirm:
                ack_message(); break;
            case NLME_SYNC_confirm:
                process_update_request(); break;
            case NO_PRIMITIVE:
                if(!ZigBeeStatus.flags.bits.bNetworkFormed)
                    process_network_formation();
                else if (ZigBeeReady() && bIsBound && bSendUpdate)
                {
                    TxBuffer[TxData++] = PointerPositionByte; /* send message */
                    currentPrimitive = APSDE_DATA_request;
                }
                if(myStatusflags.bits.bBindSwitchToggled)
                    bind_process();
        }
    }
}
```

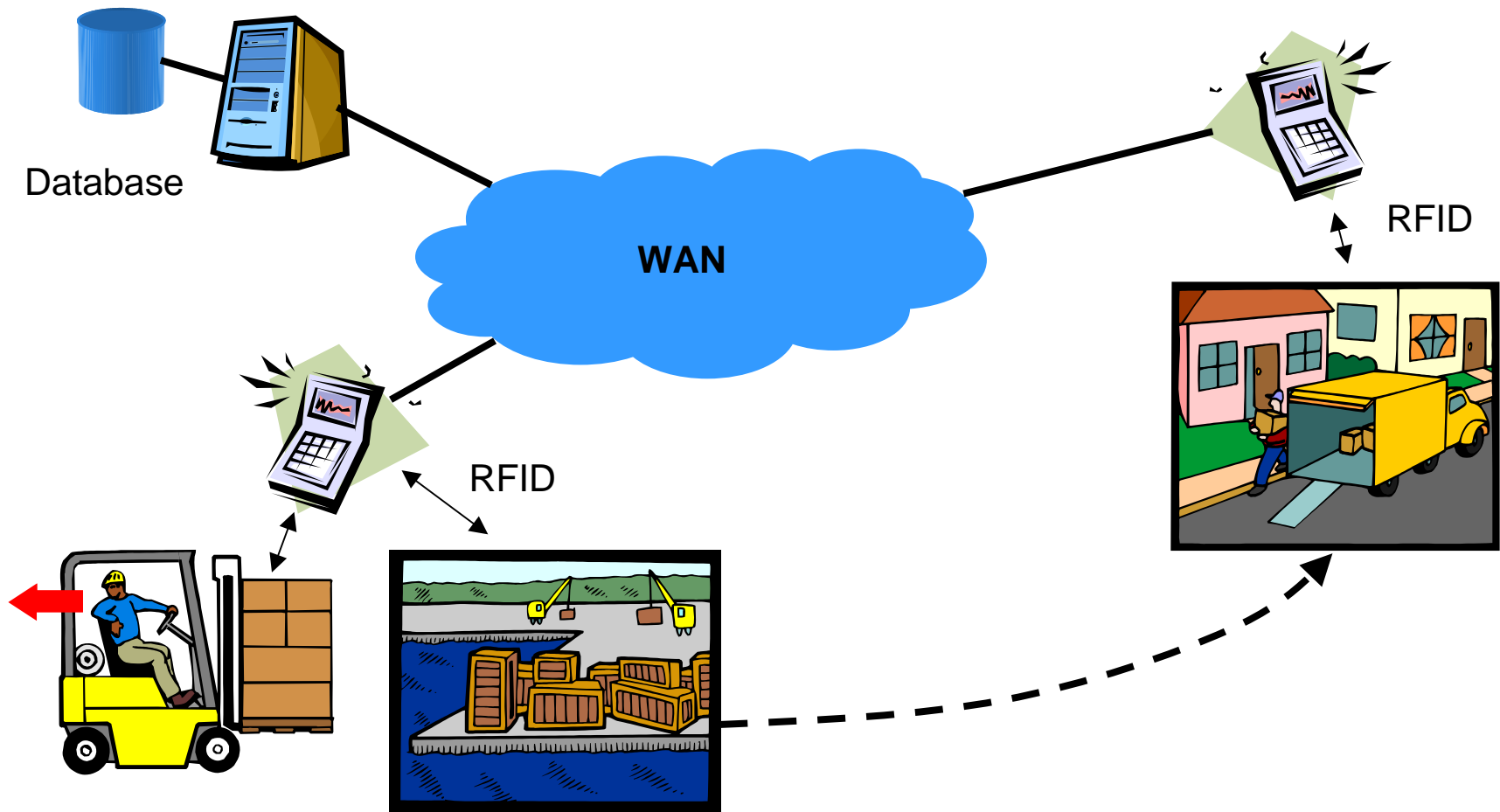
Reference: CC #189, p. 60

# Endpoint Code Structure

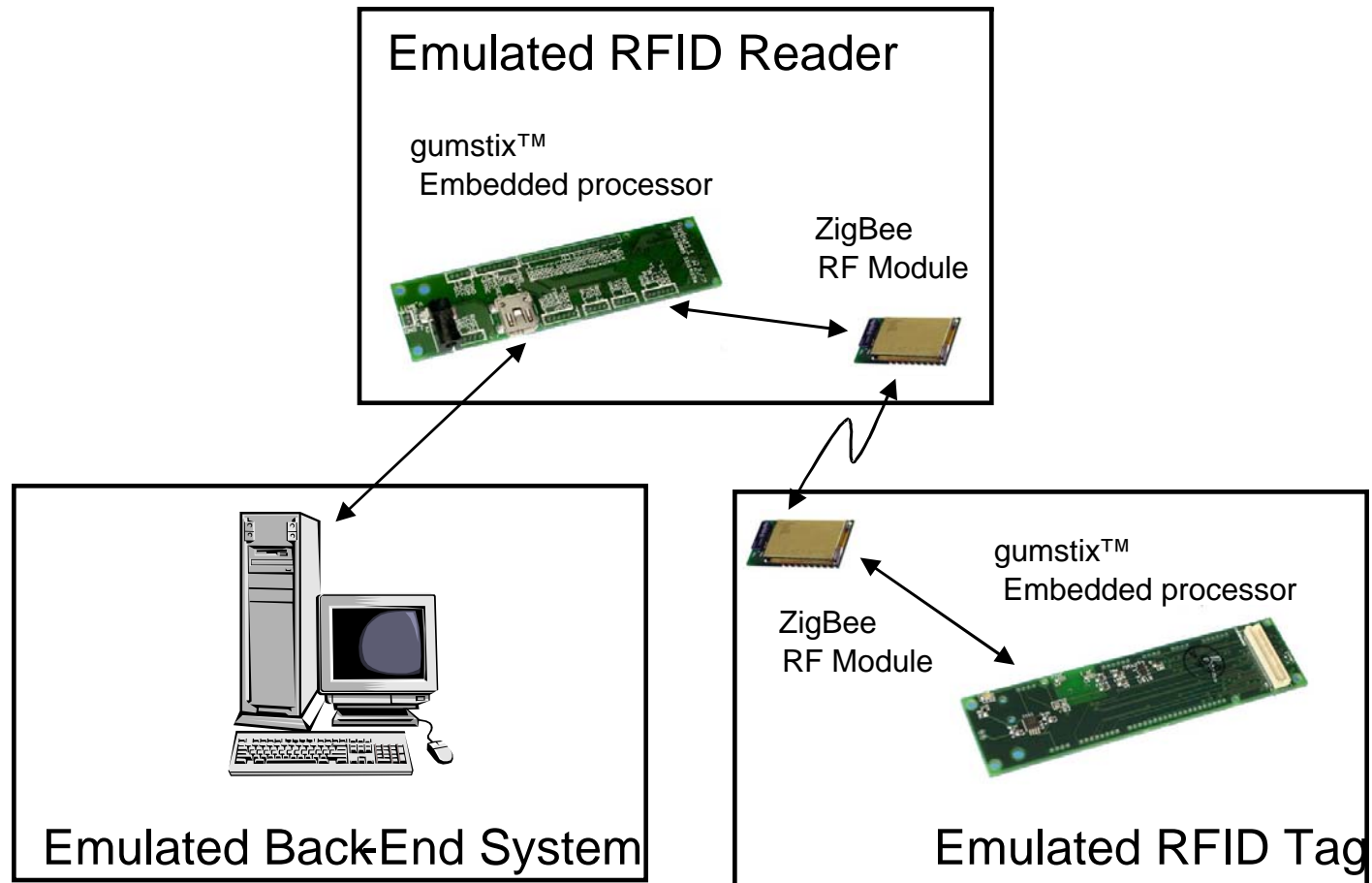
```
void main(void)
{
    currentPrimitive = NO_PRIMITIVE;
    NetworkDescriptor = NULL;
    ZigBeeInit();
    if(!blsBound) myStatusFlags.bBidSwitchToggled = TRUE;
    while(TRUE)
    {
        ZigBeeTasks( &currentPrimitive );
        switch(currentPrimitive)
        {
            case NLME_NETWORK_DISCOVERY_confirm:
                form_network(); break;
            case NLME_JOIN_confirm:
                join_network(); break;
            case APSDE_DATA_indication:
                switch (params.APSDE_DATA_indication.DstEndpoint)
                {
                    case EP_ZDO:    process_binding(); break;
                    case EP_LIGHT:  process_data(); break;
                }
            case APDSE_DATA_confirm:
                ack_message(); break;
            case NLME_SYNC_confirm:
                process_update_request(); break;
            case NO_PRIMITIVE:
                join_bind();
        }
        if ( (currentPrimitive == NO_PRIMITIVE) && myProcessesAreDone() )
        {
            SLEEP();
            currentPrimitive = NMLE_SYNC_request;
        }
    }
}
```

Reference: CC #189, p. 61

# Variations on a Theme



# Prototype RFID System



# Homework #7

- Identify three applications for the Stock Clock or a similar system architecture (other than the stock tracking or weather applications described in the article)
  - Consider the duty cycle that would be required and available power from reasonable batteries. What is the operating lifetime of your applications?
  - Identify alternative sensor inputs and actuators needed for your application
  - For my RFID application, I have chosen the low-power Maxstream XBee™ module ([www.maxstream.net](http://www.maxstream.net)). Using this device or any other you might find on the Internet, estimate the communications range of your system. If this doesn't meet the needs for your system, consider using ZigBee routers
    - how would this influence the system operating lifetime?