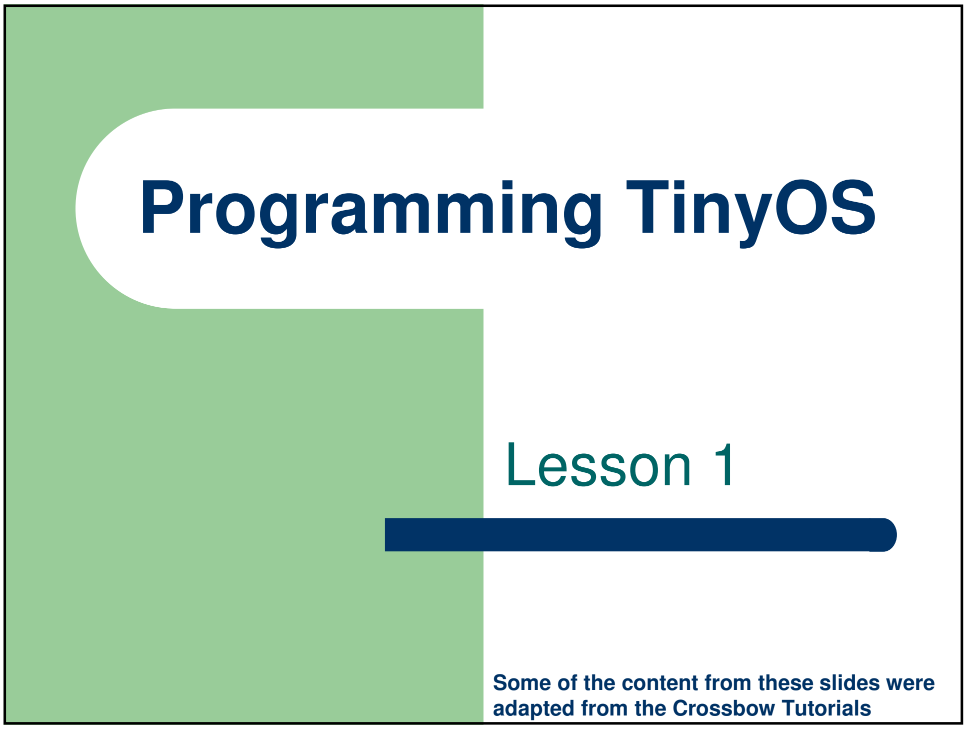
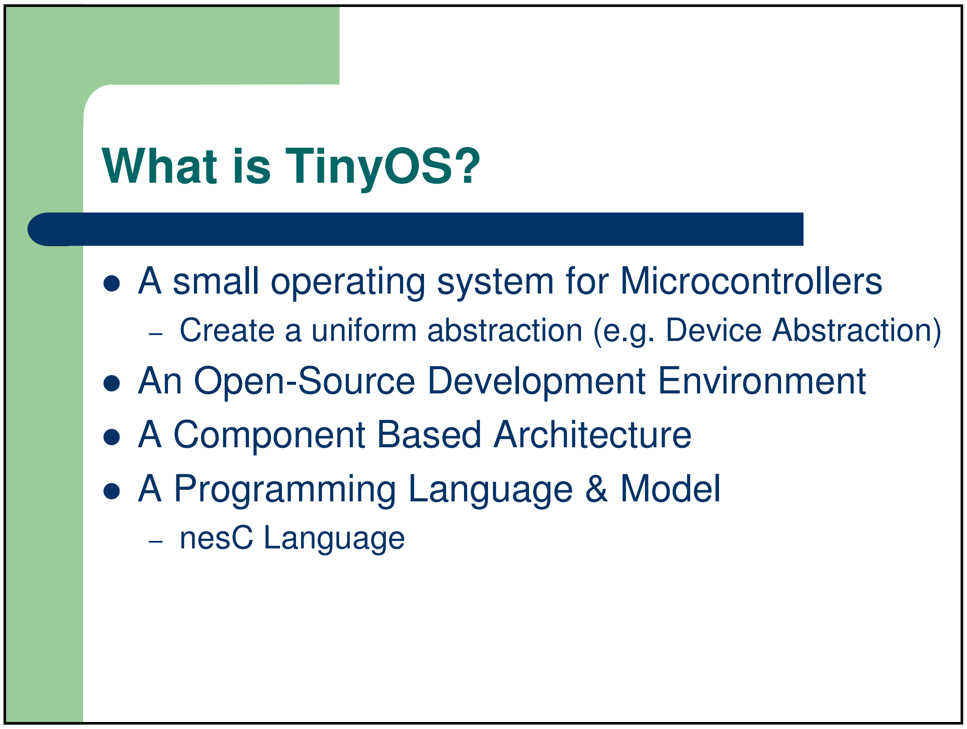


Programming TinyOS

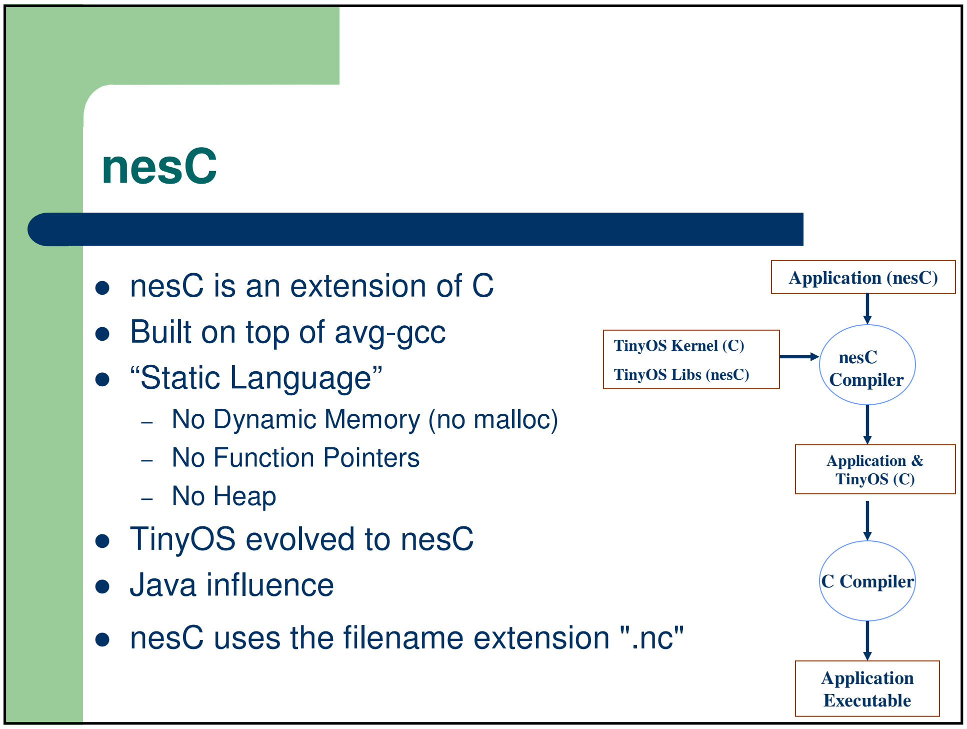
Lesson 1

Some of the content from these slides were adapted from the Crossbow Tutorials



What is TinyOS?

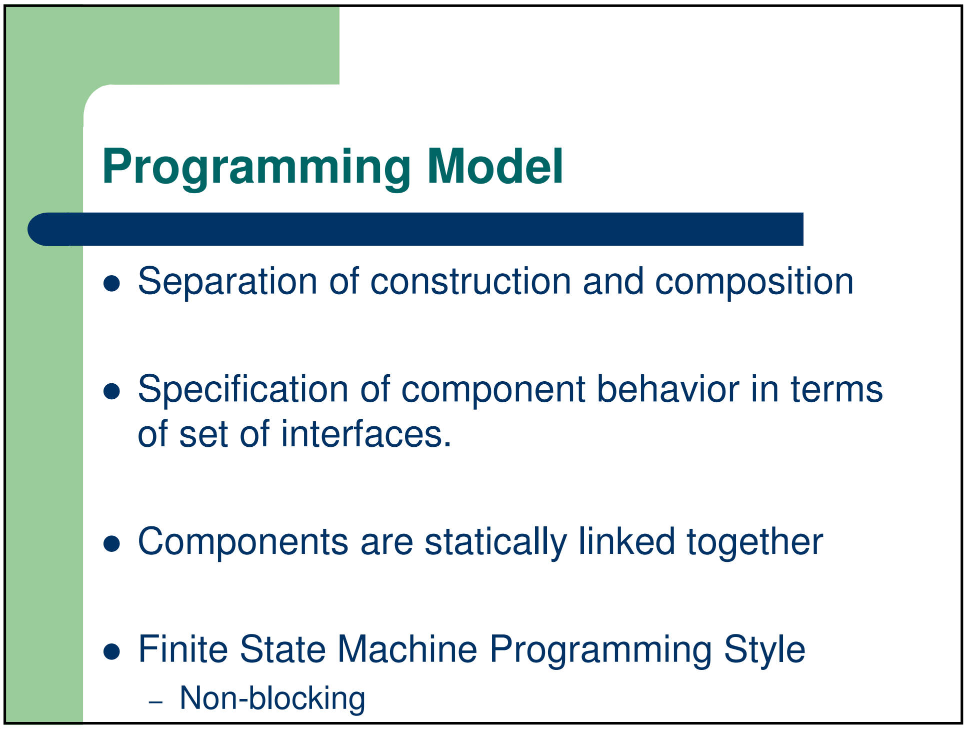
- A small operating system for Microcontrollers
  - Create a uniform abstraction (e.g. Device Abstraction)
- An Open-Source Development Environment
- A Component Based Architecture
- A Programming Language & Model
  - nesC Language



nesC

- nesC is an extension of C
- Built on top of avg-gcc
- “Static Language”
  - No Dynamic Memory (no malloc)
  - No Function Pointers
  - No Heap
- TinyOS evolved to nesC
- Java influence
- nesC uses the filename extension ".nc"

Application (nesC)
TinyOS Kernel (C)
TinyOS Libs (nesC)
nesC Compiler
Application & TinyOS (C)
C Compiler
Application Executable

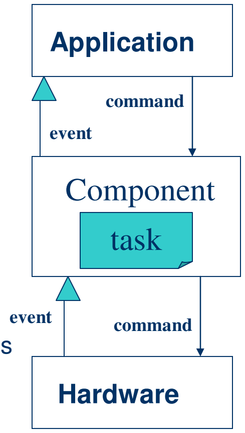


Programming Model

- Separation of construction and composition
- Specification of component behavior in terms of set of interfaces.
- Components are statically linked together
- Finite State Machine Programming Style
  - Non-blocking

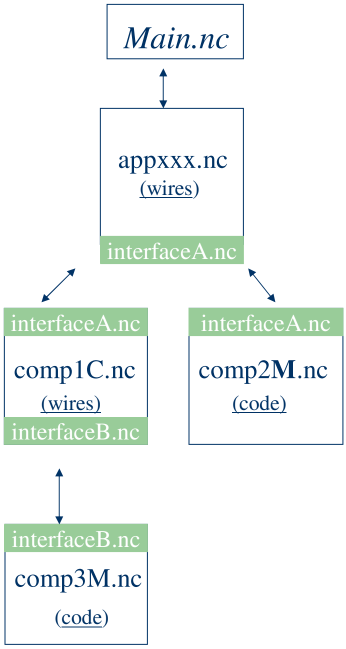
Basic Constructs

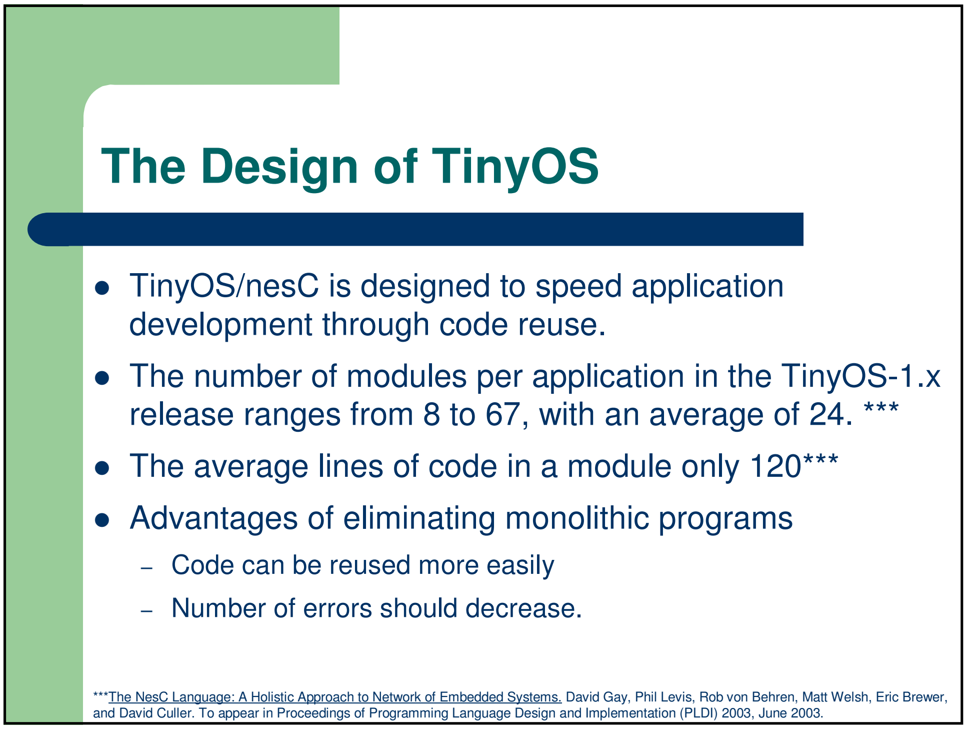
- Commands – Cause action to be initiated.
- Events – Call back to notify action has occurred and give results.
- Tasks – Background computation, non-time critical
- Modules – Component implemented with C Code
- Configurations – Component implemented with Wires
- Interfaces – specifications of bi-directional communications for the components



Basic Concepts

- **Interfaces** (xxx.nc)
  - Specifies functionality to outside world
  - what commands can be called
  - what events need handling
- Software Components
  - **Module** (xxxM.nc)
    - Code implementation
    - Code for **Interface** functions
  - **Configuration** (xxxC.nc)
    - Linking/wiring of components
    - When top level app, drop C from filename xxx.nc

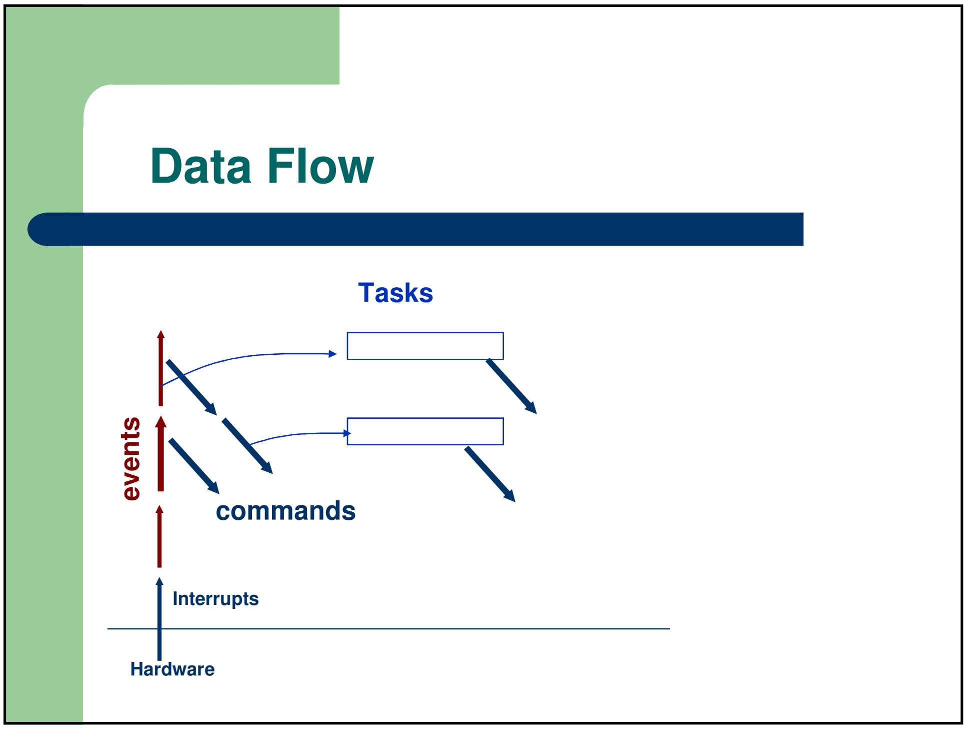




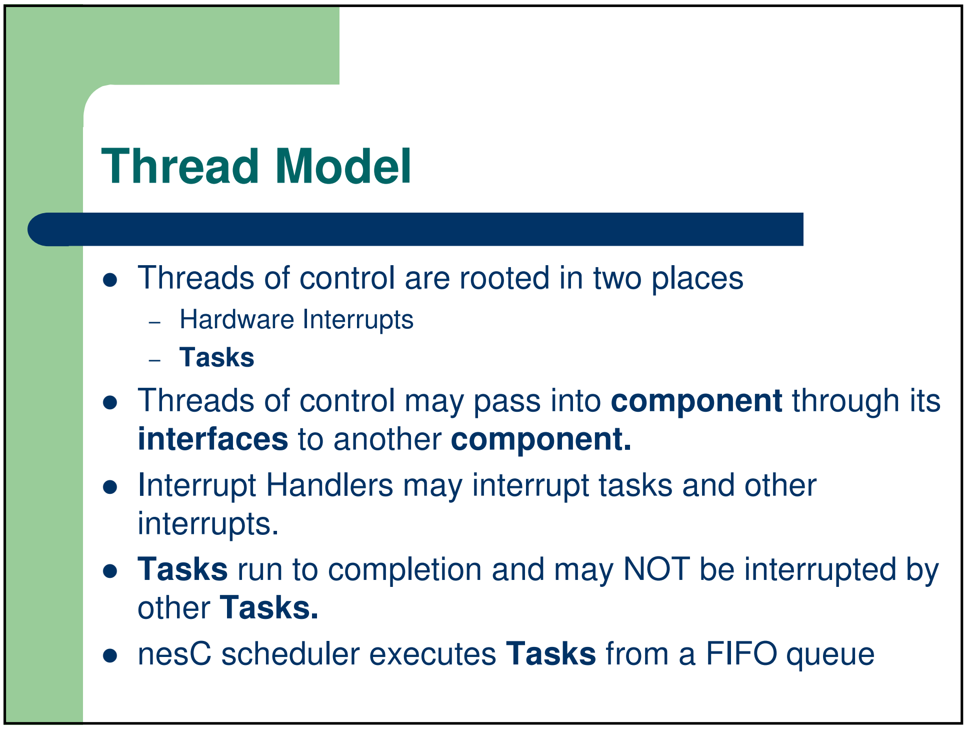
The Design of TinyOS

- TinyOS/nesC is designed to speed application development through code reuse.
- The number of modules per application in the TinyOS-1.x release ranges from 8 to 67, with an average of 24. ***
- The average lines of code in a module only 120***
- Advantages of eliminating monolithic programs
  - Code can be reused more easily
  - Number of errors should decrease.

***The NesC Language: A Holistic Approach to Network of Embedded Systems. David Gay, Phil Levis, Rob von Behren, Matt Welsh, Eric Brewer, and David Culler. To appear in Proceedings of Programming Language Design and Implementation (PLDI) 2003, June 2003.

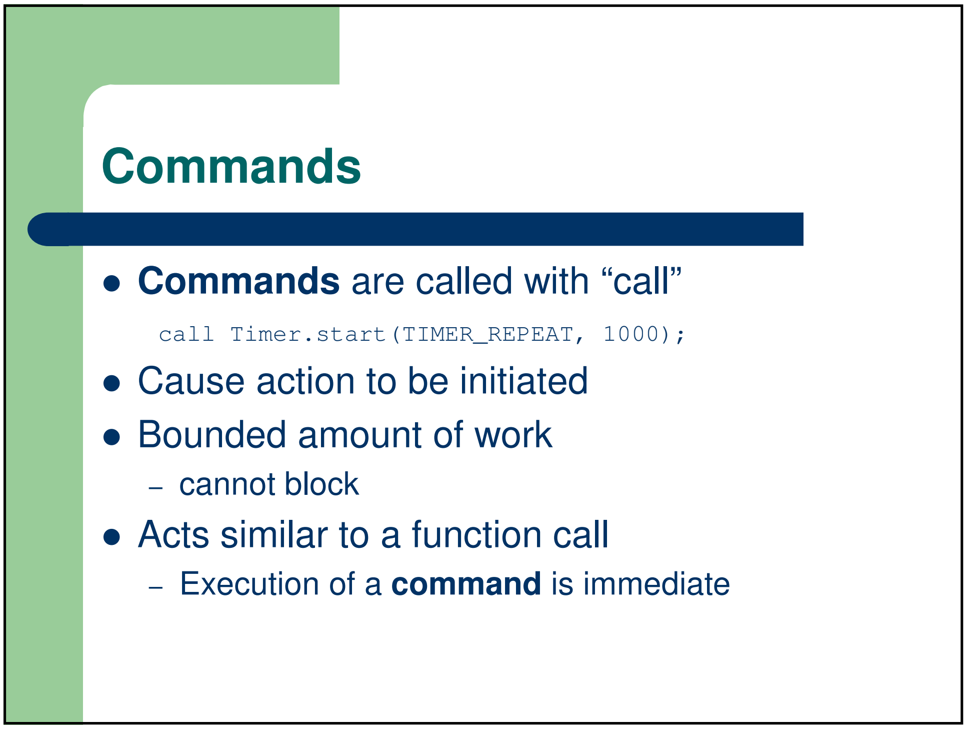


Data Flow



Thread Model

- Threads of control are rooted in two places
  - Hardware Interrupts
  - **Tasks**
- Threads of control may pass into **component** through its **interfaces** to another **component.**
- Interrupt Handlers may interrupt tasks and other interrupts.
- **Tasks** run to completion and may NOT be interrupted by other **Tasks.**
- nesC scheduler executes **Tasks** from a FIFO queue

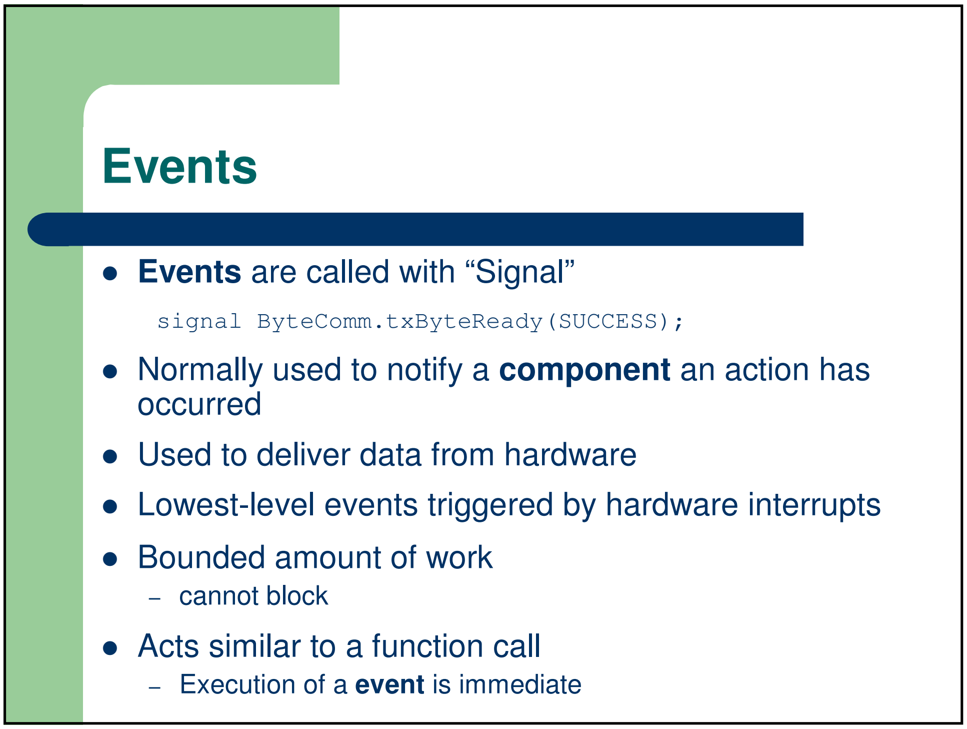


Commands

- **Commands** are called with “call”

```
call Timer.start(TIMER_REPEAT, 1000);
```

- Cause action to be initiated
- Bounded amount of work
  - cannot block
- Acts similar to a function call
  - Execution of a **command** is immediate

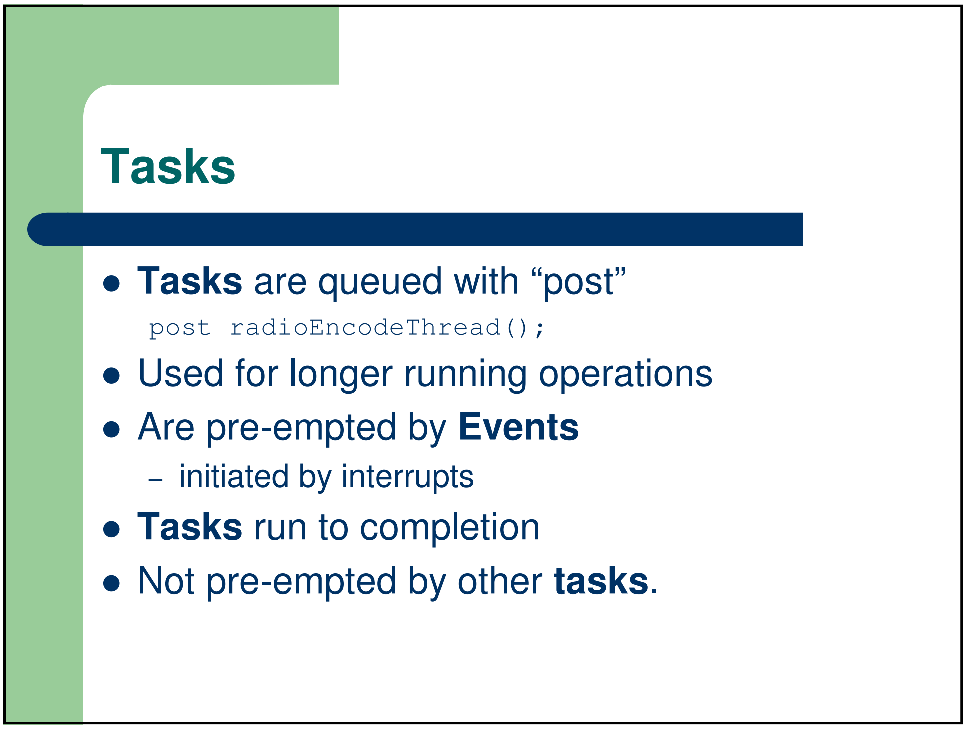


Events

- **Events** are called with “Signal”

```
signal ByteComm.txByteReady(SUCCESS);
```

- Normally used to notify a **component** an action has occurred
- Used to deliver data from hardware
- Lowest-level events triggered by hardware interrupts
- Bounded amount of work
  - cannot block
- Acts similar to a function call
  - Execution of a **event** is immediate

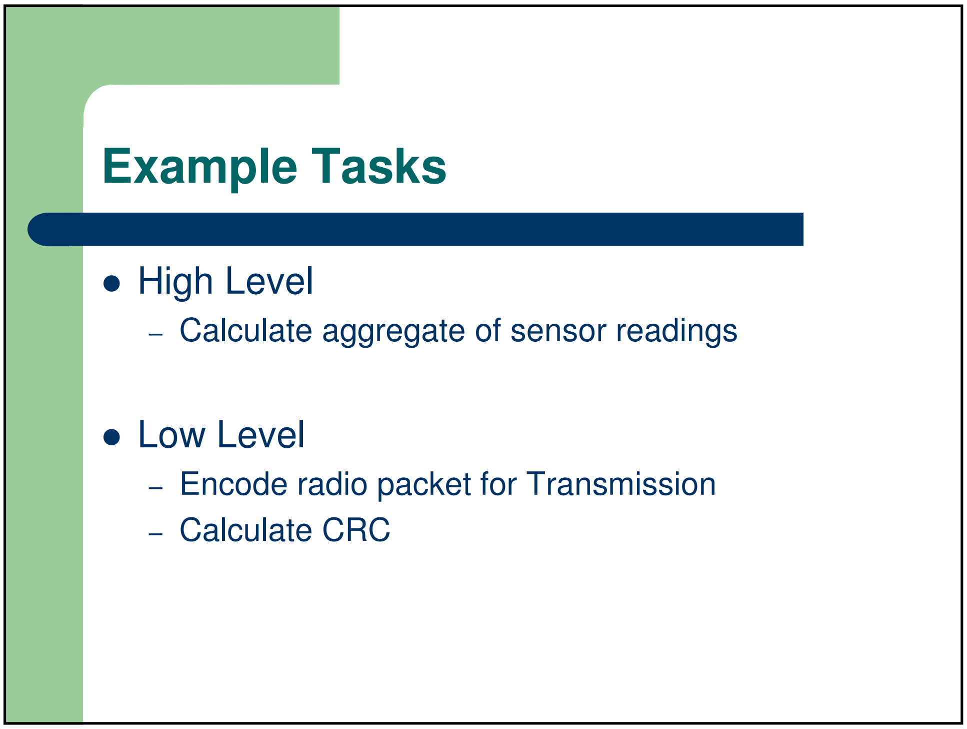


Tasks

- **Tasks** are queued with “post”

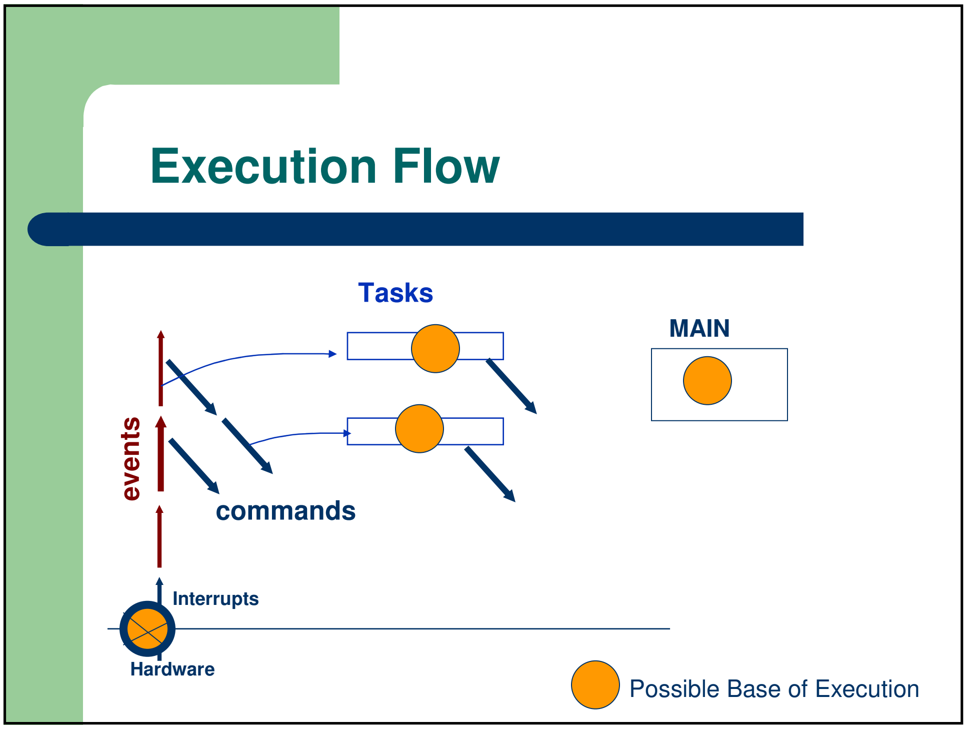
```
post radioEncodeThread();
```

- Used for longer running operations
- Are pre-empted by **Events**
  - initiated by interrupts
- **Tasks** run to completion
- Not pre-empted by other **tasks.**



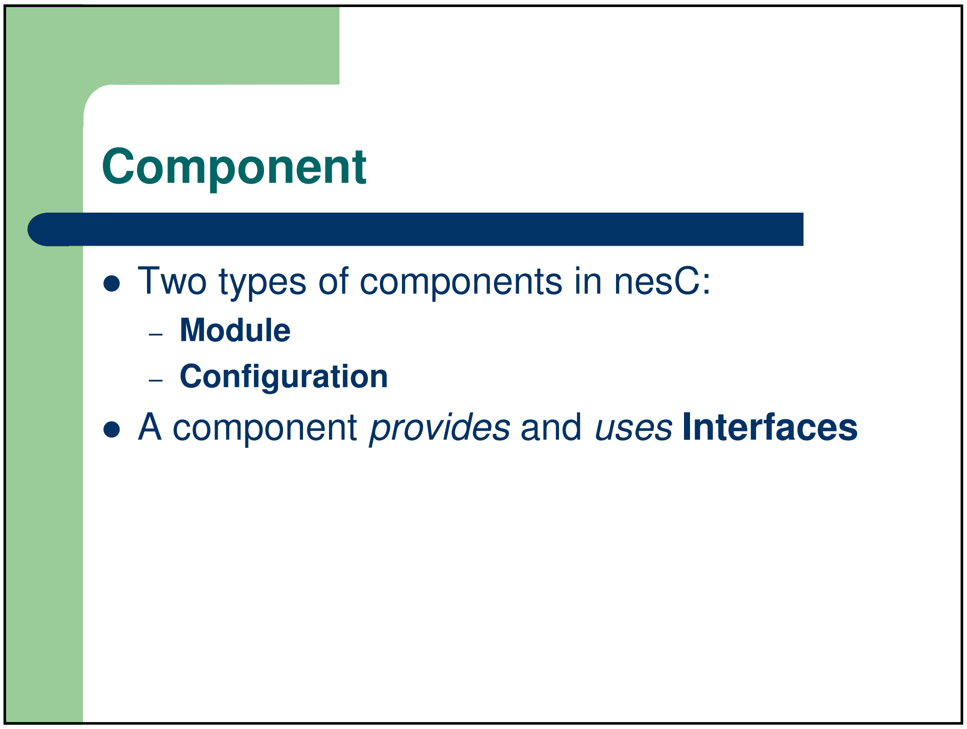
Example Tasks

- High Level
  - Calculate aggregate of sensor readings
- Low Level
  - Encode radio packet for Transmission
  - Calculate CRC



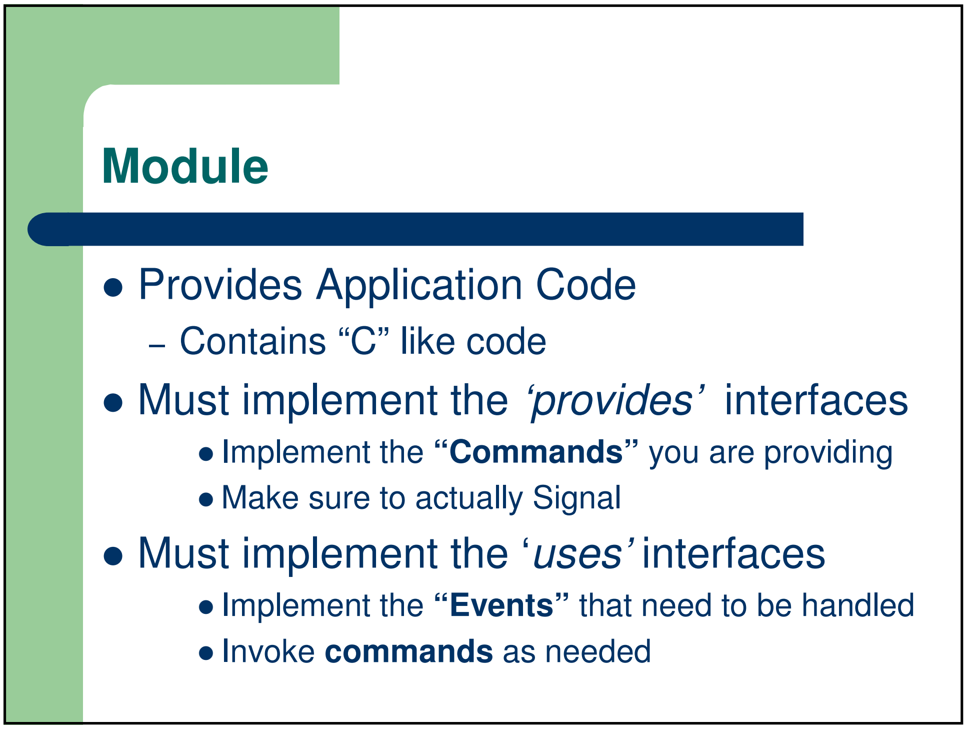
Execution Flow

● Possible Base of Execution



Component

- Two types of components in nesC:
  - **Module**
  - **Configuration**
- A component *provides* and *uses* **Interfaces**



Module

- Provides Application Code
  - Contains “C” like code
- Must implement the *‘provides’* interfaces
  - Implement the **“Commands”** you are providing
  - Make sure to actually Signal
- Must implement the ‘*uses’* interfaces
  - Implement the **“Events”** that need to be handled
  - Invoke **commands** as needed

Configuration

- A **configuration** is a **component** that "wires" other **components** together.
- **Configurations** are used to assemble other **components** together
- Connects **interfaces** used by **components** to **interfaces** provided by others.

Interfaces

- Specifies the behavior between **components**.
- Bi-directional multi-function interaction channel between two components.
  - Allows a single interface to represent a complex event
    - E.g., a registration of some event, followed by a callback
    - Critical for non-blocking operation
  - Provided interfaces
    - Represent the functionality that the component provides to its user
    - "**Commands**" are functions to be implemented by the interface's provider
  - Used interfaces
    - Represent the functionality that the component needs
    - "**Events**" are functions to be implemented by the interface's user

Interface Example

```
Interface SendMsg {
   command result_t send(uint16_t address, uint8_t length,
                                              TOS_MsgPtr msg);
   event result_t sendDone(TOS_MsgPtr msg, result_t success);
}
```

```
call SendRFM.send( TOS_BCAST_ADDR, sizeCurrentPkt, sendMsg);
```

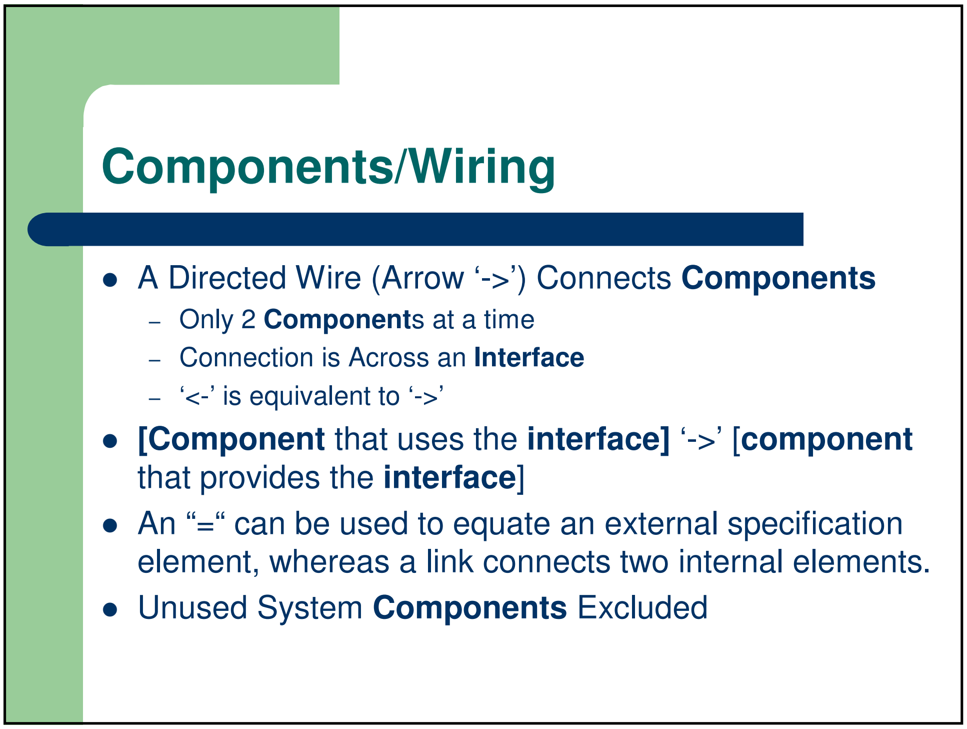
```
 provides {
   interface StdControl as Control;
 }
 uses {
….
   interface SendMsg as SendRFM;
   interface ReceiveMsg as ReceiveRFM;
   interface SendMsg as SendWriteRFM;
```

```
event result_t SendRFM.sendDone(
       TOS_MsgPtr msg, result_t success)
   {

     return SUCCESS;
   }
```

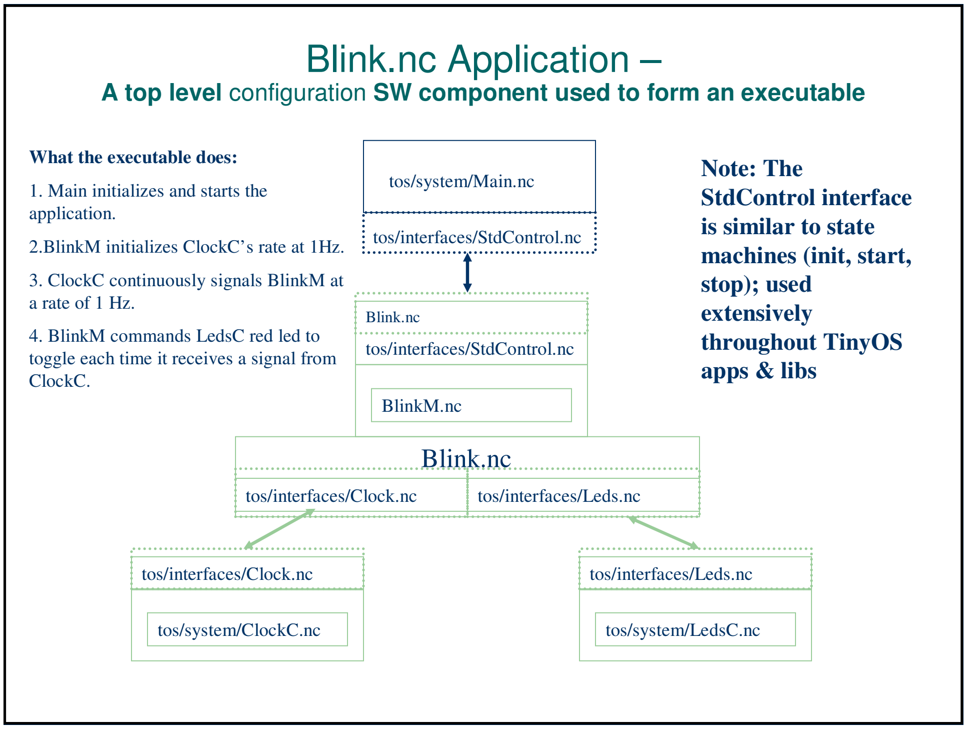
Application

- Consists of one or more **components**, **wired together** to form a runnable program
- Has a single **top-level configuration** that specifies the set of components in the application and how they connect one another
- Connected wire to main component to start execution



Components/Wiring

- A Directed Wire (Arrow '->') Connects **Components**
  - Only 2 **Component**s at a time
  - Connection is Across an **Interface**
  - '<-' is equivalent to '->'
- **[Component** that uses the **interface]** '->' [**component** that provides the **interface**]
- An "=" can be used to equate an external specification element, whereas a link connects two internal elements.
- Unused System **Components** Excluded



Blink.nc Application –

A top level configuration **SW component used to form an executable**

What the executable does:

1. Main initializes and starts the application.

2.BlinkM initializes ClockC's rate at 1Hz.

3. ClockC continuously signals BlinkM at a rate of 1 Hz.

4. BlinkM commands LedsC red led to toggle each time it receives a signal from ClockC.

Note: The StdControl interface is similar to state machines (init, start, stop); used extensively throughout TinyOS apps & libs

Tips

- Your friend is grep or “find in files”
- Look at example applications in the /apps directory.
- Try to keep commands and events short.
  - Avoid long loops