MODULE 2:
TinyOS

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TinyOS

- History of TinyOS
- Implementation
- Requirements motivating the design of TinyOS
- Component Model, Interfaces.
- TinyOS computational concepts.
- Overview of TinyOS Execution Model:
- Concurrency
- TinyOS Theory of Execution:
  - Events & Tasks,
  - TinyOS Architecture.
  - TinyOS-Programming Model.

TinyOS

- TinyOS is an open source, BSD-licensed operating system designed for low-power wireless devices, such as those used in sensor networks, ubiquitous computing, personal area networks, smart buildings, and smart meters.
  - (BSD → Berkeley Software Distribution, a Unix-like operating system.)
- TinyOS is an embedded, component-based operating system and platform for low-power wireless devices, such as those used in wireless sensor networks (WSNs), smartdust, ubiquitous computing, personal area networks, building automation, and smart meters.
- It is written in the programming language nesC, as a set of cooperating tasks and processes.

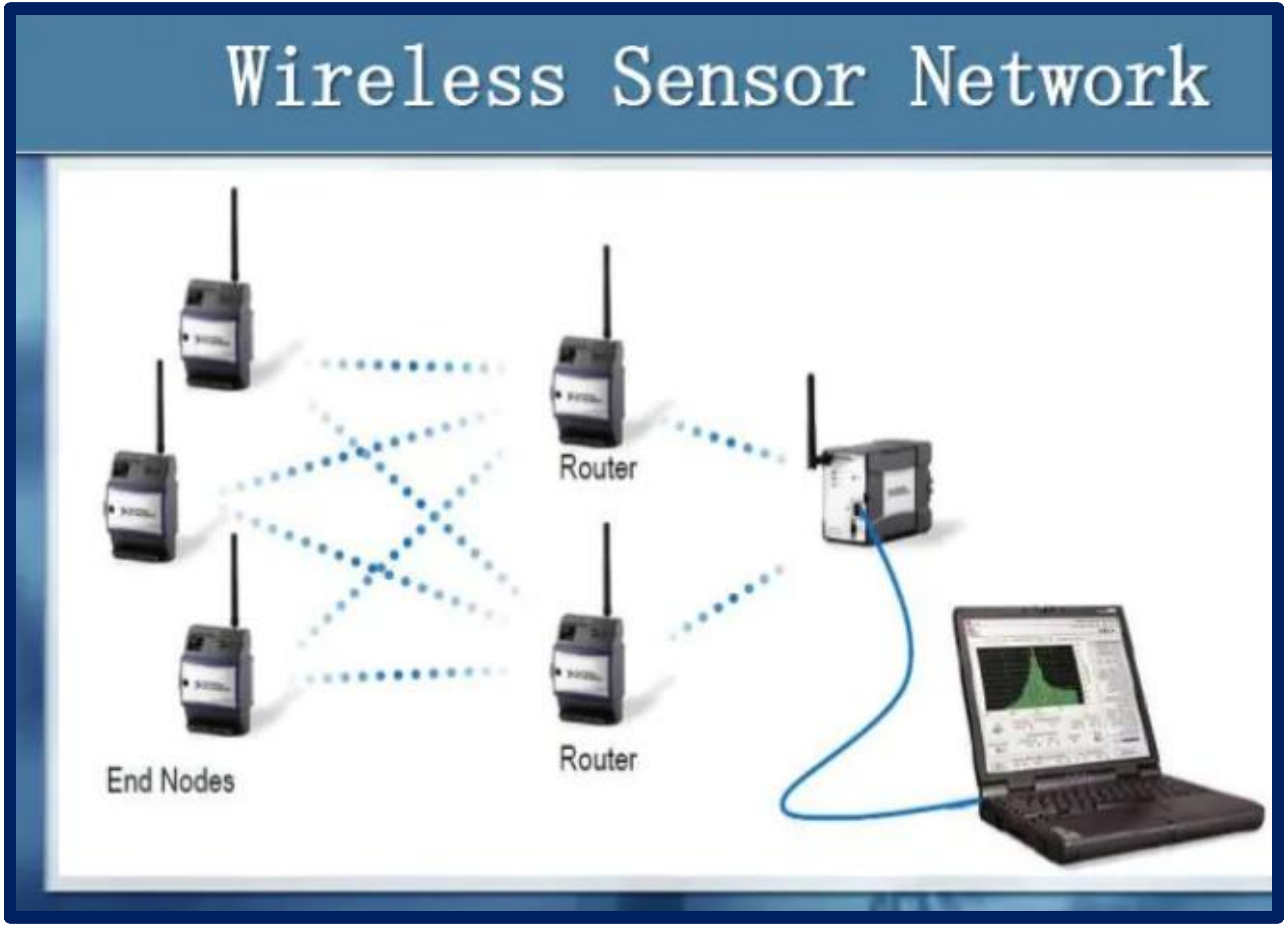
NEED OF TinyOS

- Problems with traditional OS : –
  - Multithreaded Architecture not useful
  - Large Memory Footprint
  - Does not help to conserve energy and power
- Requirements for Wireless Sensor Network: –
  - Efficient utilization of energy and power
  - Small Footprint and support diversity in design usage

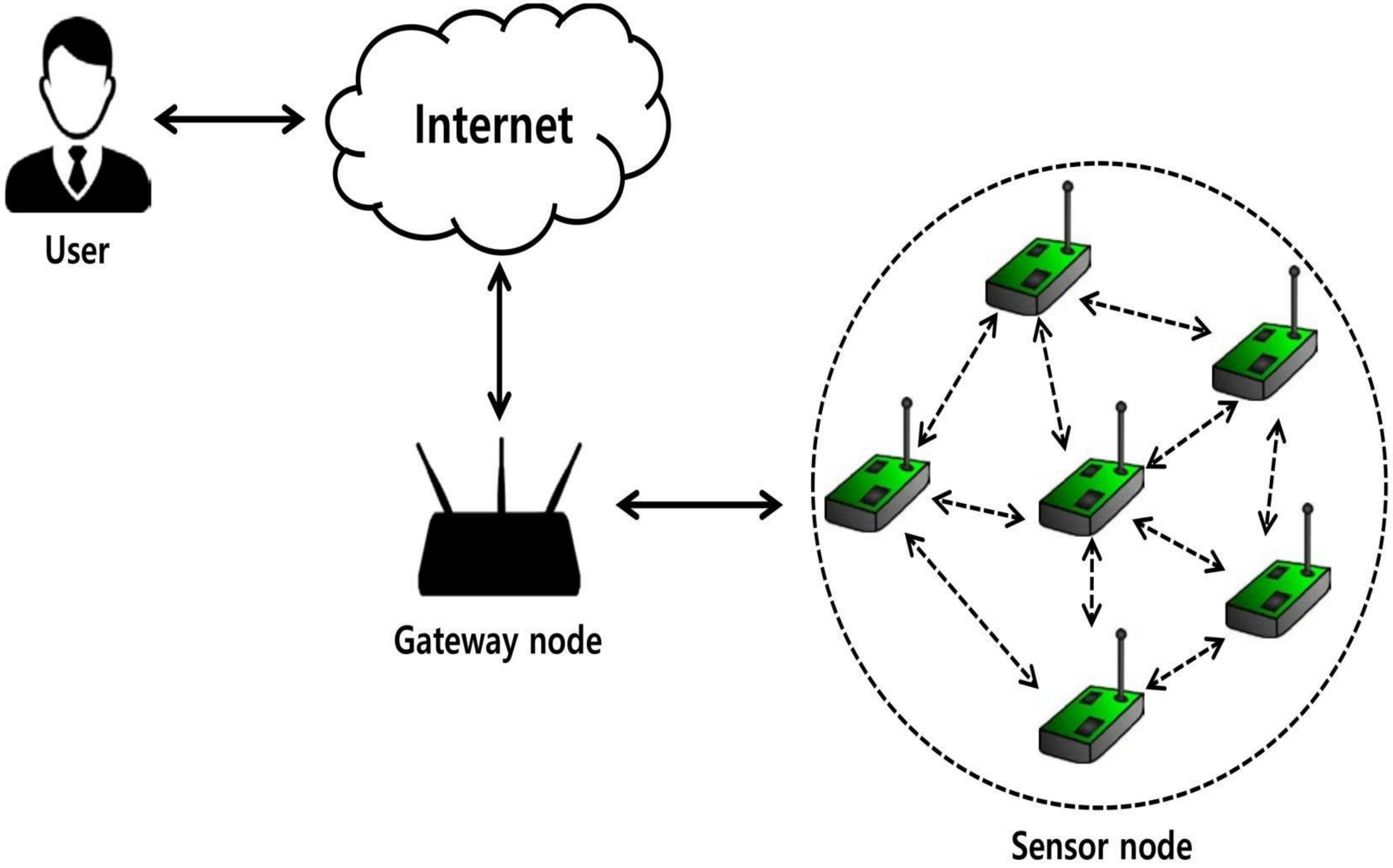
NEED OF TinyOS (CONTINUED)

WSN (Wireless Sensor Network) –

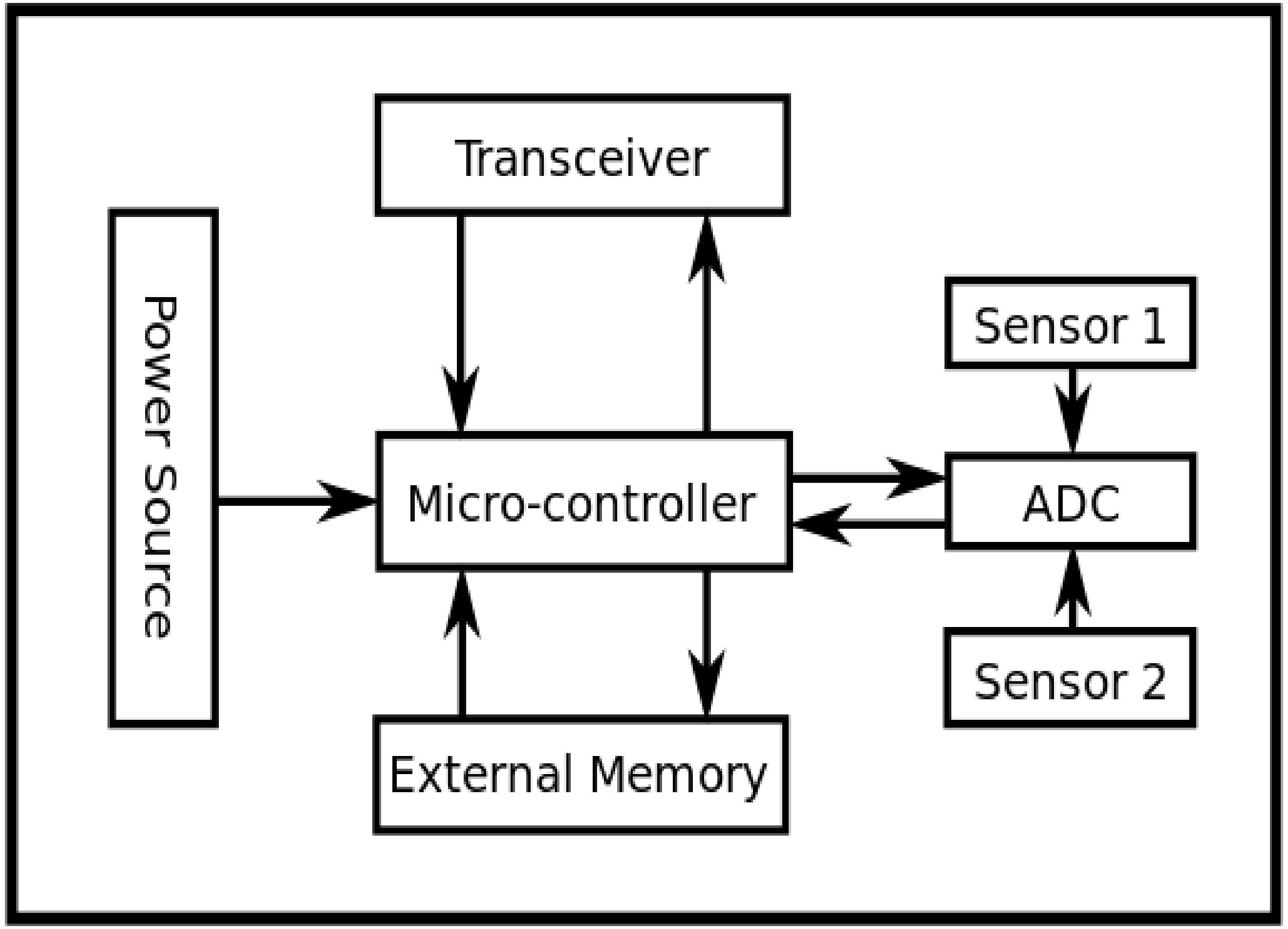
- **It mainly use broadcast communication.**
- **Wireless Sensing + Data Networking**
- **Consist of sensor networks which have – Low power, limited power, energy constrained due to small size.**
- **Large number of heterogeneous sensor node devices spread over a large field.**


Wireless Sensor Network
Router
Router
End Nodes

WSN



Typical Architecture Of Sensor Node



Operating System For WSN

- TinyOS
- ContikiOS
- MANTIS
- SOS
- Nano-RK

Wireless Application Areas

Environmental Monitoring

Air/ Climate

Water/ Soil

Indoor Monitoring

Resource Monitoring

Power Monitoring

Solar Monitoring

Wind Farm Monitoring

Industrial Measurements

Structural Health Monitoring

Machine Condition Monitoring

Process Monitoring

WHAT IS TinyOS?

- TinyOS is a free open source operating system.
- Designed for WSN
- TinyOS began as a collaboration between University of California, Berkeley and Intel Research
- An embedded operating system written in nesC language.
- nesC → component-based, event-driven programming language used to build applications for the TinyOS platform.
- It features a component based architecture.

TinyOS DESIGN MODELS

Component-based model (Modularity):

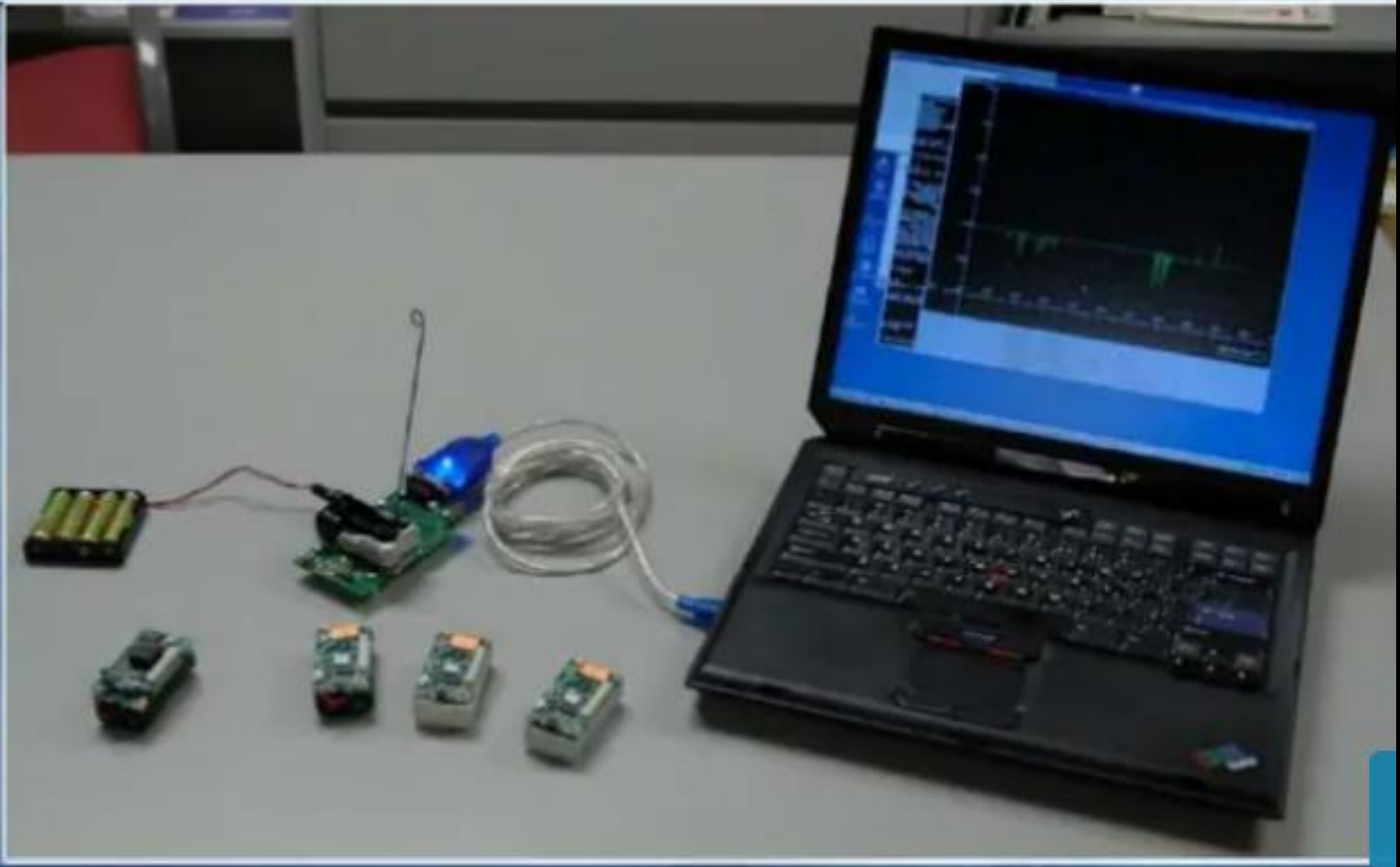
- Simple functions are incorporated in components with clean interfaces.
- Complex functions can be implemented by complex components.

TinyOS DESIGN MODELS

Event-based Model

- Interact with outside by events (no command shell)
- There are two kinds of events for TinyOS:
  - External events – Clock events and message events
  - Internal events – triggered by external events

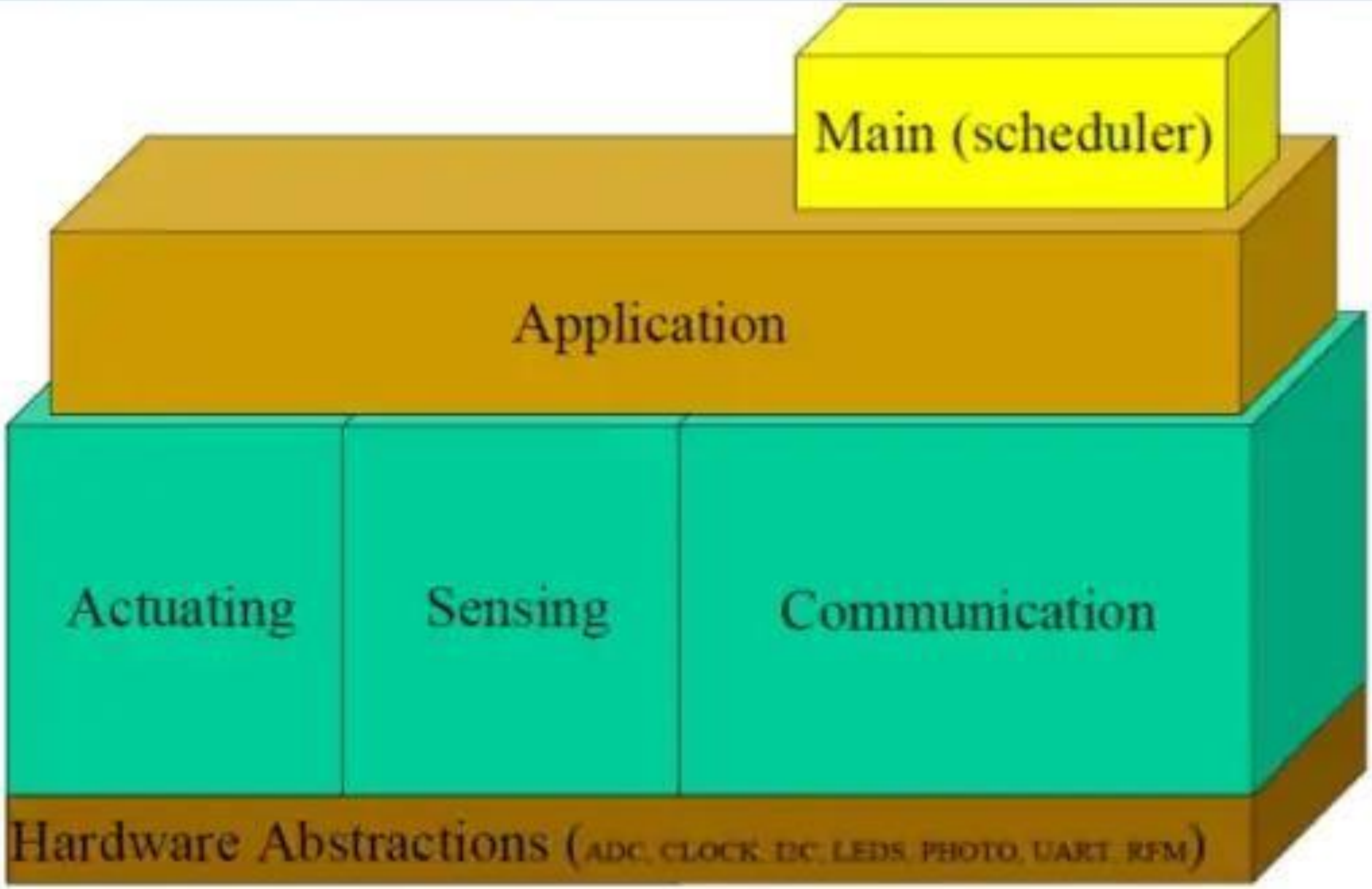
Hardware setup Overview



FEATURES OF TinyOS

- ✓ Completely non-blocking
- ✓ Programs are built out of software components.
- ✓ Tasks are non-preemptive and run in FIFO order.
- ✓ TinyOS code is statically linked

Structure of TinyOS



Main (scheduler)

Application

Actuating

Sensing

Communication

Hardware Abstractions (ADC, CLOCK, I2C, LEDS, PHOTO, UART, RFM)

TinyOS AS A SOLUTION

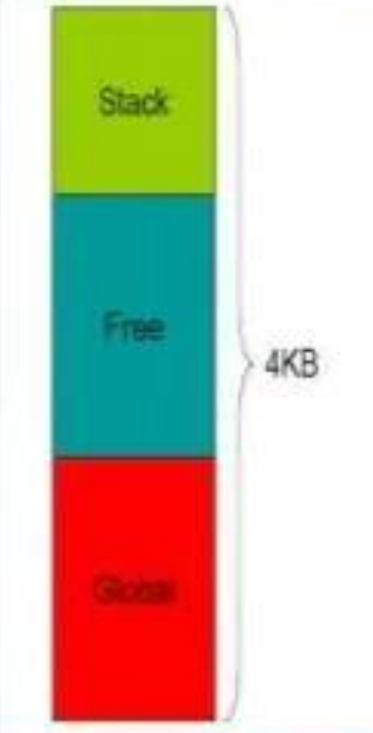
- Component based architecture allows frequent changes while still keeping the size of code minimum.
- Event based execution model means no user/kernel boundary and hence supports high concurrency.
- It is power efficient as it makes the sensors sleep as soon as possible.
- Has small footprint as it uses a non-preemptable FIFO task scheduling.

TinyOS MODELS

- Data Model
- Thread Model
- Programming Model
- Component Model
- Network Model

Data Memory Model

- **Static Memory Allocation**
  - No Heaps or any other dynamic structures used.
  - Memory requirements determined at compile time.
  - *This increases the runtime efficiency.*
- **Global variables**
  - Allocated on per frame basis.
- **Local Variables**
  - Saved on the stack
  - Defined in the function/method



THREAD MODEL

Power-Aware Two-levels Scheduling

- **Long running tasks and interrupt events**
- **Sleep unless tasks in queue, wakeup on event**

Tasks

- **Time-flexible, background jobs**
- **Atomic with respect to other tasks**
- **Can be preempted by events**

Events

- **Time-critical, shorter duration**
- **Last-in first-out semantic (no priority)**
- **Can post tasks for deferred execution**

PROGRAMMING MODEL

Separation Construction/Composition

Construction of Modules:

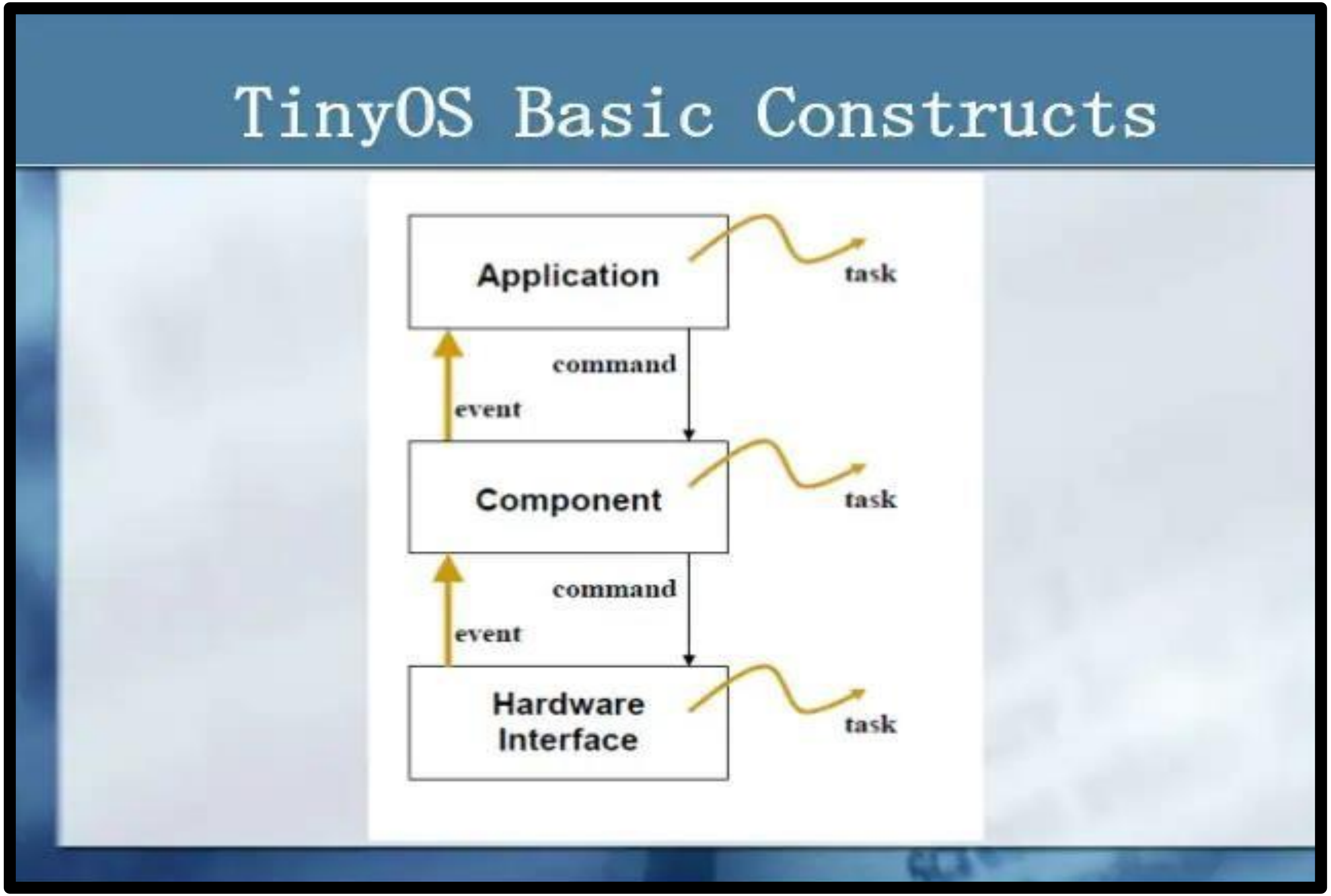
- ✓ Modules implementation similar to C coding
- ✓ Programs are built out of components
- ✓ Each component specifies an interface
- ✓ Interfaces are “hooks” for wiring components

Composition of Configurations:

- ✓ Components are statically wired together
- ✓ Increases programming efficiency (code reuse) an runtime efficiency

Component Model

- Components should use and provide **bidirectional interfaces.**
- Components should **call** and **implement commands** and **signal** and **handle events.**
- Components must handle events of used interfaces and also provide interfaces that must implement commands.



TinyOS Basic Constructs

TinyOS Computational Concepts

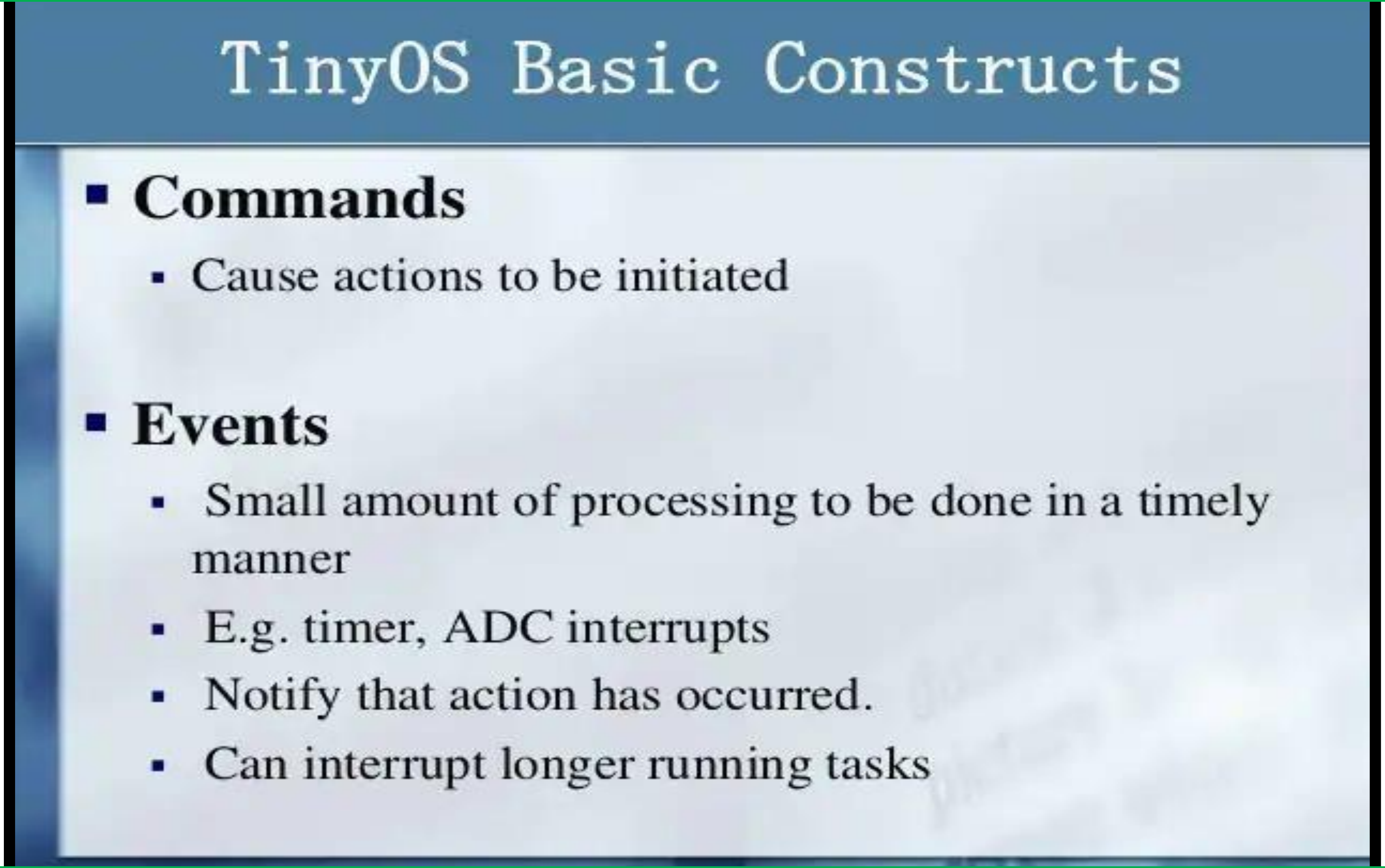
i. Event

ii. Command

iii. Task

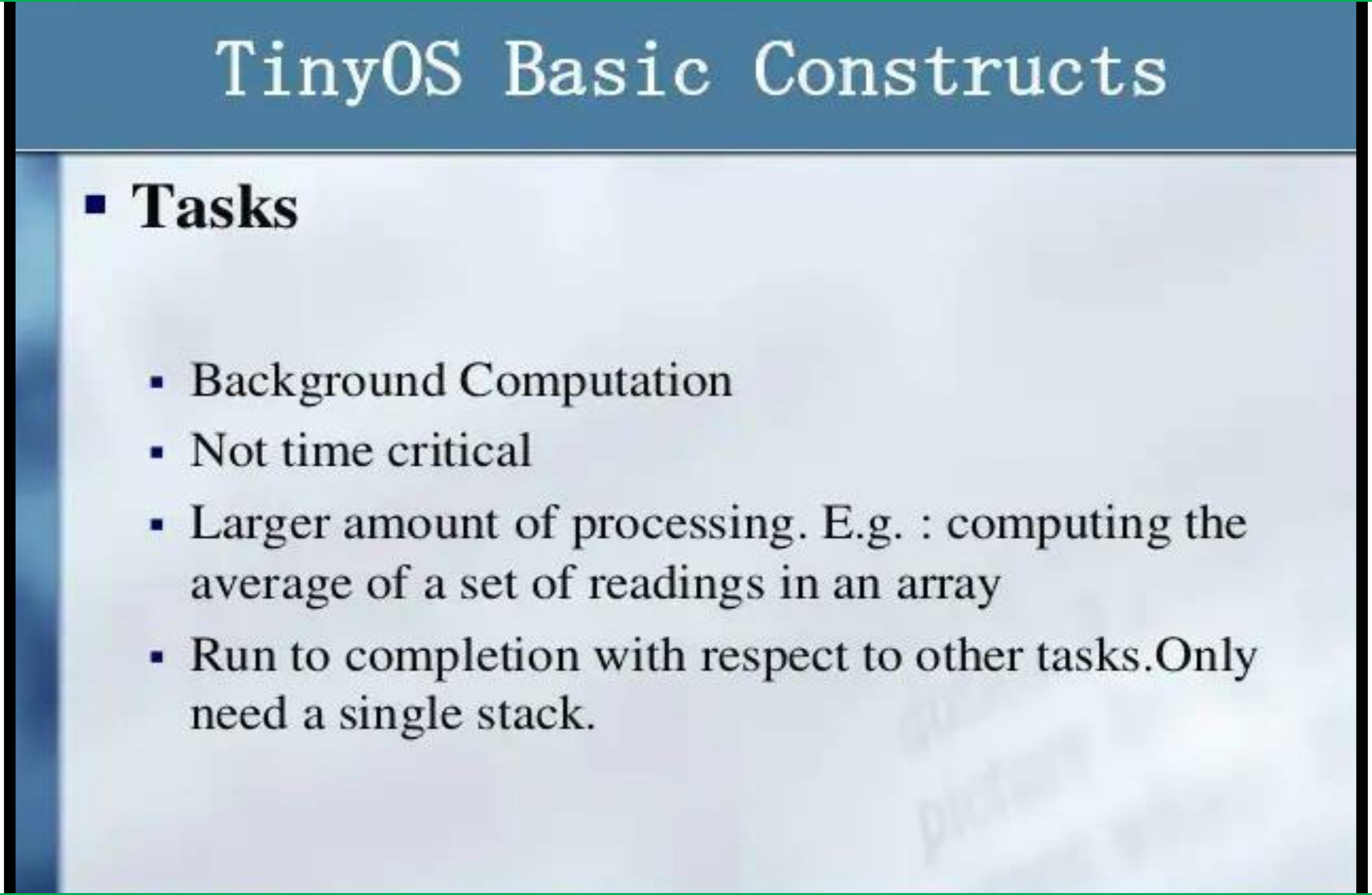
Tinyos Computational Concepts

1. Events
   - Time critical
   - Caused by interrupts (Timer, ADC, Sensors)
   - Short duration
2. Commands
   - Request to a component to perform service (e.g, start sensor reading)
   - Non-blocking, need to return status
   - Postpone time-consuming work by posting a task (split phase w/ callback event)
   - Can call lower-level commands
3. Tasks
   - Time flexible (delayed processing)
   - Run sequentially by TOS Scheduler
   - Run to completion with respect to other tasks
   - Can be preempted by events



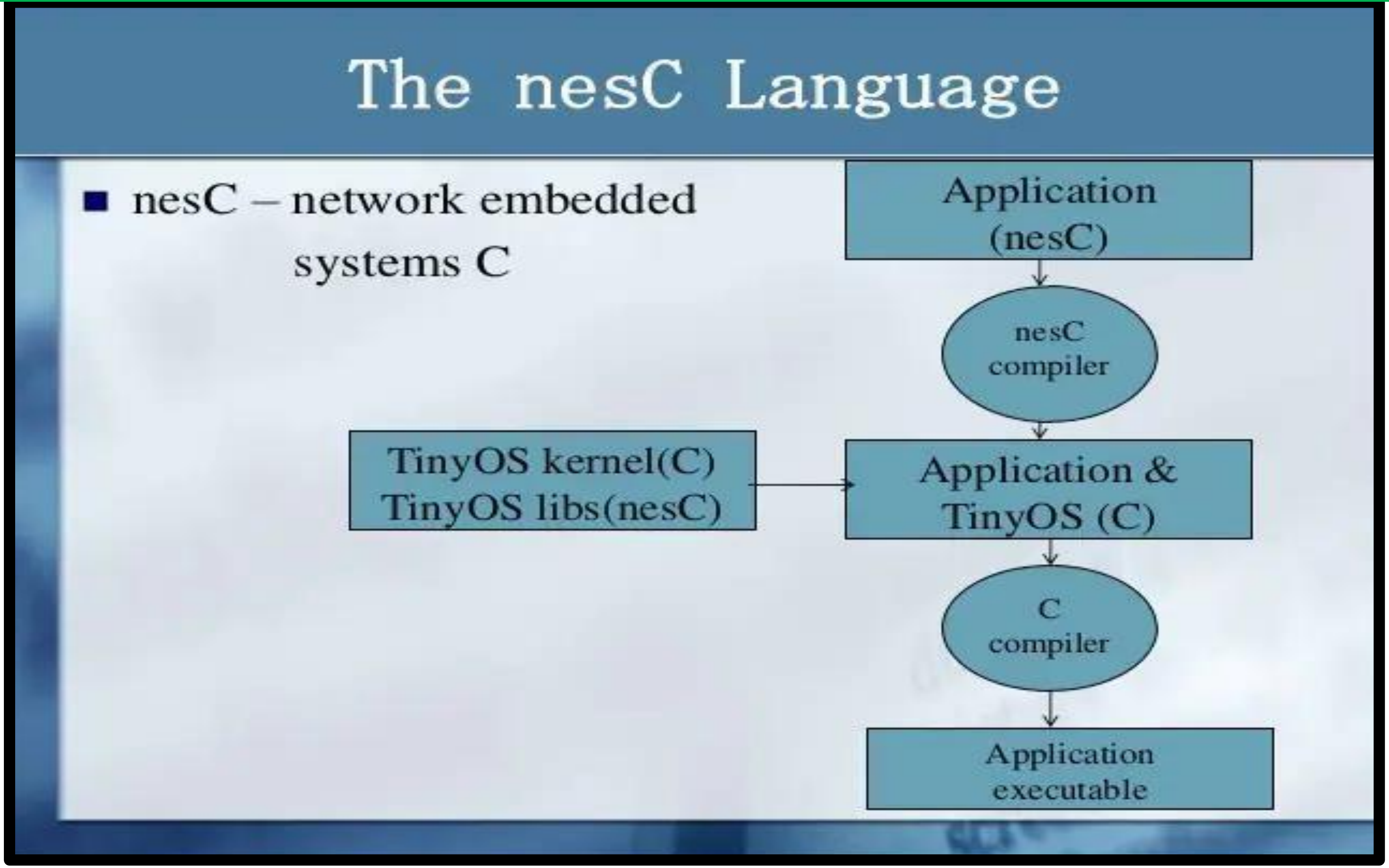
TinyOS Basic Constructs

- **Commands**
  - Cause actions to be initiated
- **Events**
  - Small amount of processing to be done in a timely manner
  - E.g. timer, ADC interrupts
  - Notify that action has occurred.
  - Can interrupt longer running tasks



TinyOS Basic Constructs

- **Tasks**
  - Background Computation
  - Not time critical
  - Larger amount of processing. E.g. : computing the average of a set of readings in an array
  - Run to completion with respect to other tasks.Only need a single stack.



The nesC Language

- nesC – network embedded systems C

Application (nesC)

nesC compiler

TinyOS kernel(C)
TinyOS libs(nesC)

Application & TinyOS (C)

C compiler

Application executable

The nesC Language

- An **extension** to the **C programming language**, embody the concepts and execution model of TinyOS.
- Filename extension **.nc**

Static language

- **No dynamic memory** (malloc)
- **No** function **pointers**
- **No heap**
- Includes task **FIFOscheduler**
- Designed to encourage **code reuse.**

THE nesC LANGUAGE

- ✓nesC (pronounced "NES-see") is a component-based, event-driven programming language used to build applications for the TinyOS platform.
- ✓TinyOS is an operating environment designed to run on embedded devices used in distributed wireless sensor networks.
- ✓nesC is built as an extension to the C programming language with components "wired" together to run applications on TinyOS.
- ✓The name nesC is an abbreviation of "network embedded systems C".