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Outline

- RAIC overview.
- An example of dependable application in the RAIC architectural style.
- Conclusions and related work.

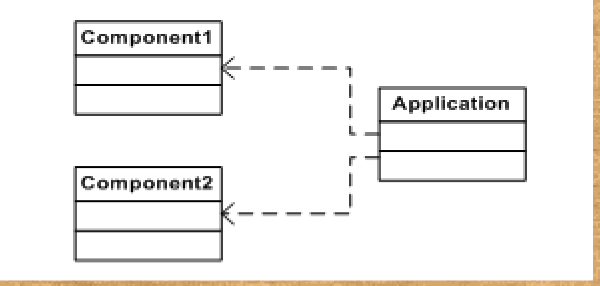
RAIC Overview

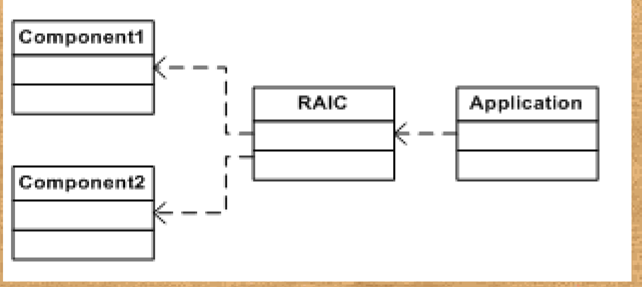
- Redundant Arrays of Independent Components
- A *redundant software component array* is a group of independent software component that provide identical, similar, or related functions.

[Liu, Richardson (2002)] UCI-ICS-TR-02-09.

[Liu, Richardson (2002)] COMPSAC 2002 Workshop of Dependable On-line Upgrading of Distributed Systems, Oxford.

The RAIC Architectural Style





- Goal: to reduce component integration cost.

[Liu, Richardson (2002)] Submitted to FSE-10.

RAIC Details

- Component Array Types
  - Component Types
  - Component Relations
- RAIC Controllers
- RAIC Levels
- RAIC Invocation Models

Array Types

- Static
- Dynamic
  - UDDI
  - Jini lookup service

Component Types

- Stateless
- Stateful
  - State-preserving function calls
  - State-changing function calls
  - State-defining function calls

  - State-independent return values
  - State-dependent return values

Component Relations

- Interface relations
- Functionality relations
- Domain relations
- Snapshot relations
- Relations on security, invocation prices, or other aspects

RAIC Levels

- *RAIC-1: Exact mirror redundancy*
- *RAIC-2: Approximate mirror redundancy*
- *RAIC-3: Shifting lopsided redundancy*
- *RAIC-4: Fixed lopsided redundancy*
- *RAIC-5: Reciprocal redundancy*
- *RAIC-6: Reciprocal domain redundancy*
- *RAIC-0: No redundancy*

RAIC Invocation Models

- RAIC-a: Sequential invocation
- RAIC-b: Synchronous parallel invocation
- RAIC-c: Asynchronous parallel invocation

[Liu, Richardson (2002)] Preparing for Foclasa (Czech).

Light Component Code Segment (in C#)

Start Page | LightAppForm.cs [Design] | LightAppForm.cs | light-RAIC.cs | light-red.cs | light-blue.cs | light.cs

Light | TurnOff()

```
1  using System;
2  using System.Net;
3  using System.Threading;
4  using System.Runtime.Remoting;
5
6  public interface ILight
7  {
8       int TurnOn();
9       int SetIntensity(int intensity);
10      int TurnOff();
11 }
12
13 public class Light: MarshalByRefObject, ILight
14 {
15      [MethodProperty(EnumMethodProperty.enumStateDefining)]
16      public int TurnOn()
17      {
18          // ...
19      }
20      [MethodProperty(EnumMethodProperty.enumStateDefining)]
21      public int SetIntensity(int intensity)
22      {
23          // ...
24      }
25      [MethodProperty(EnumMethodProperty.enumStateDefining)]
26      public int TurnOff()
27      {
28          // ...
29      }
30      // ...
31 }
32
```

Light Application 1 Code (in C#)

```
using System;
using System.Threading;

public class LightApp
{
    public static void Main(string[] args)
    {
        int pause_in_seconds = 3;
        int number_of_passes = 50;

        Light light = new Light();

        for (int i=1; i<=number_of_passes; i++)
        {
            light.TurnOn();
            Thread.Sleep(pause_in_seconds * 1000);

            light.SetIntensity(50);
            Thread.Sleep(pause_in_seconds * 1000);

            light.TurnOff();
            Thread.Sleep(pause_in_seconds * 1000);
        }
    }
}
```

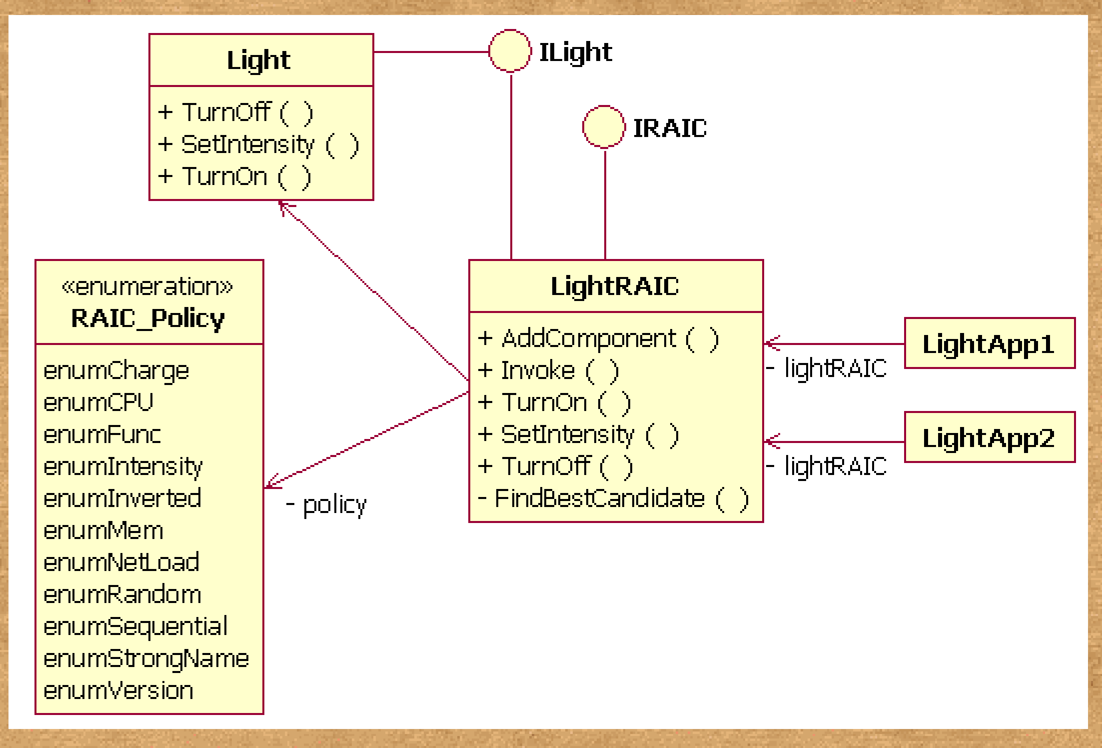
Light Application 2 Code

```
using System;
using System.Threading;

public class LightApp
{
    public static void Main(string[] args)
    {
        int pause_in_seconds = 3;
        int number_of_passes = 50;

        Light light = new Light();

        for (int i=1; i<=number_of_passes; i++)
        {
            light.TurnOn();
            Thread.Sleep(pause_in_seconds * 1000);

            light.SetIntensity(50);
            Thread.Sleep(pause_in_seconds * 1000);

            light.TurnOff();
            Thread.Sleep(pause_in_seconds * 1000);
        }
    }
}
```

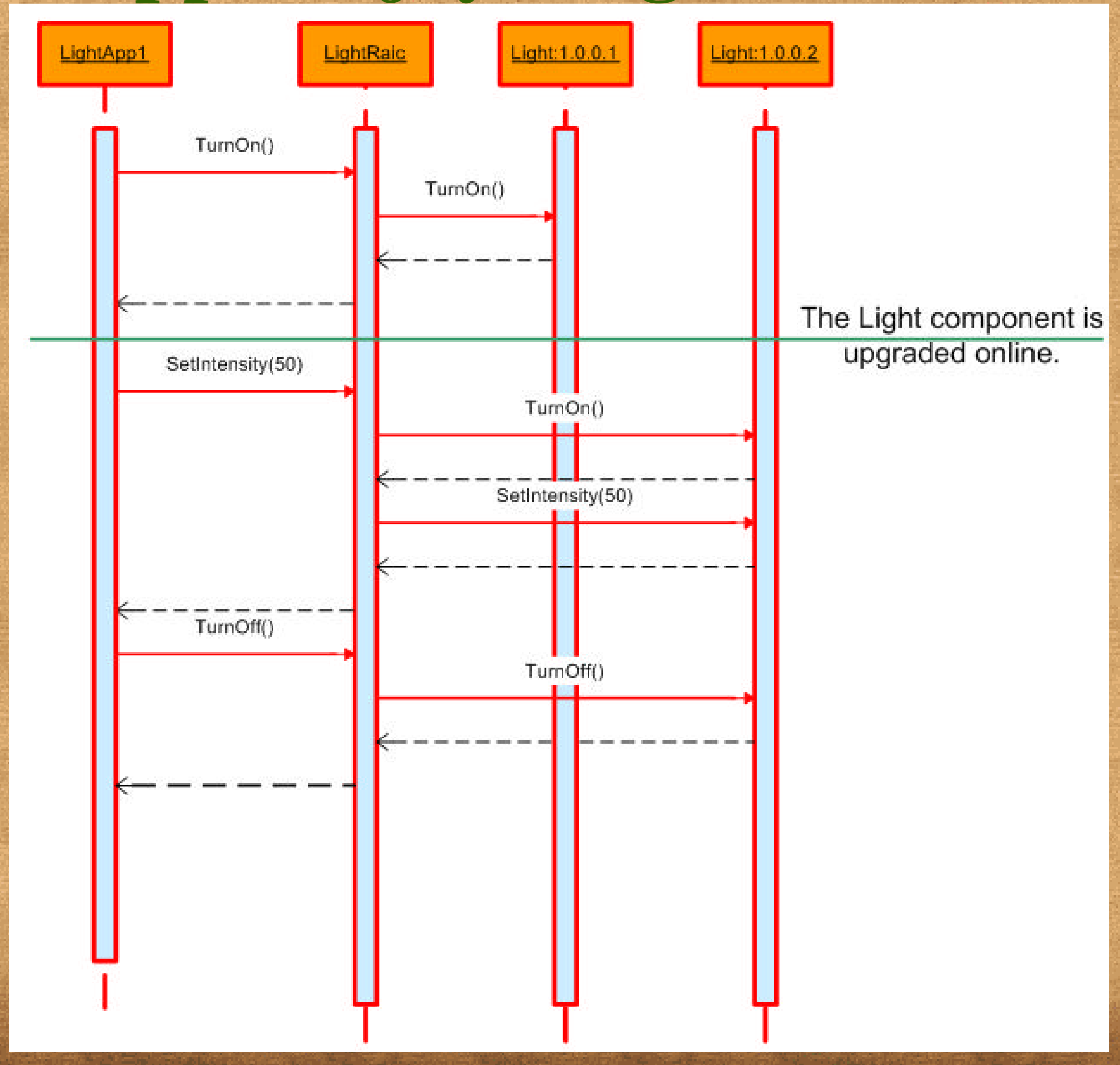
The Light Components With Versions

- Light version 1.0.0.1
  - Allows arbitrary calls to all three methods
- Light version 1.0.0.2
  - Must call *TurnOn()* before calling *SetIntensity()* or *TurnOff()*
  - Cannot call *TurnOff()* if the light is already off.

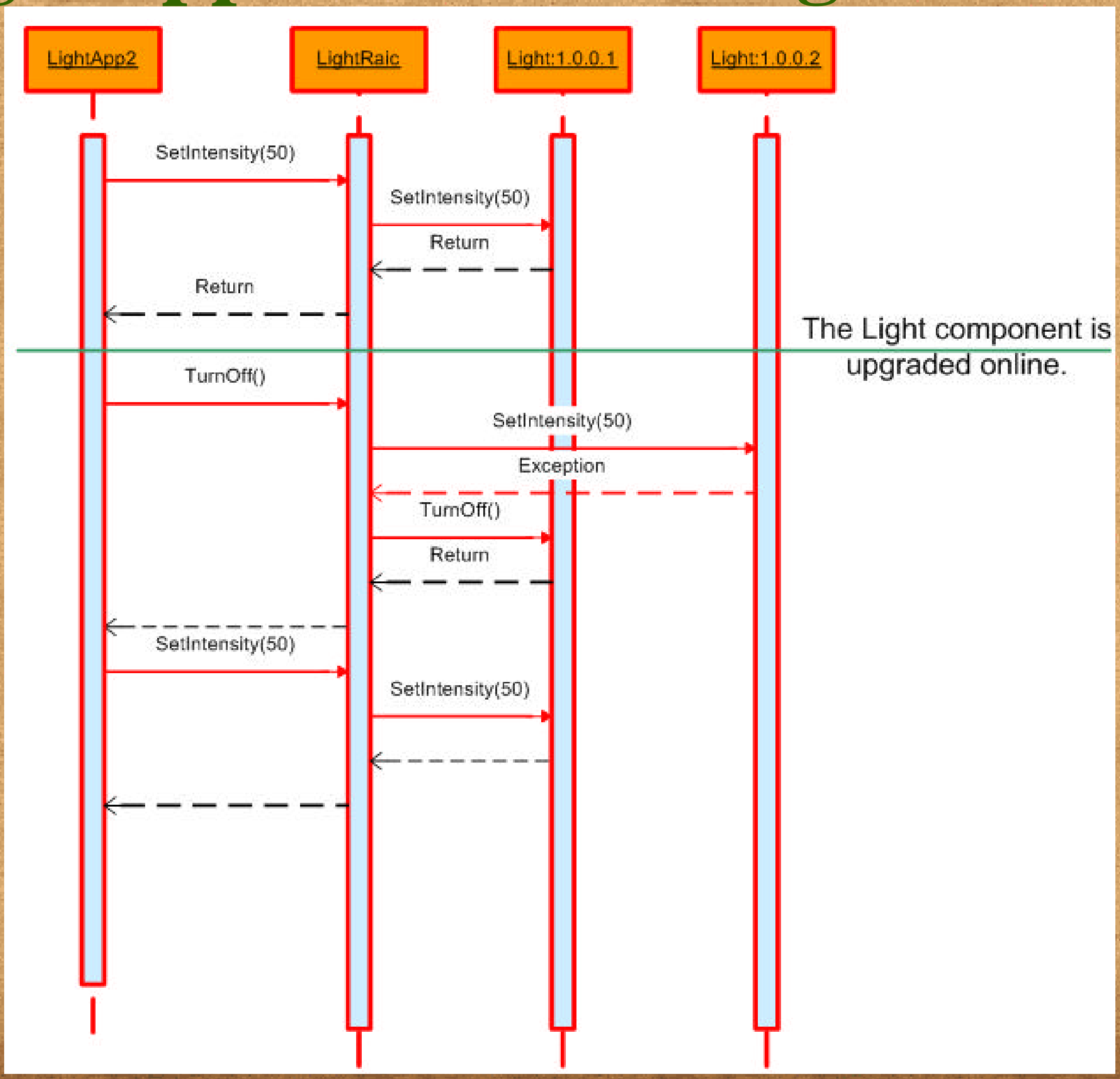
LightApp1, LightApp2, the Light Components, and LightRAIC



LightApp1 enjoys Light:1.0.0.2



LightApp2 reverts to Light:1.0.0.1



Just-In-Time Component Testing

- JIT component testing versus traditional software testing.
- JIT component testing versus perpetual testing.
  [Osterweil, L. J., L. A. Clarke, et al. (1996)]
- JIT component testing versus self-checking software or components.
  [Yau, S. S. and R. C. Cheung (1975)]
  [Liu, C. and D. J. Richardson (1998)]

JIT Testing VS Traditional Testing

- Happens even after application deployment.
- Uses heuristics and other means in place of traditional test oracles.
- Uses mostly live input data.
- Efficiency extremely important for predetermined test inputs.
- Should not change component states.

JIT Testing VS Perpetual Testing

- Perpetual testing is optional and removable.
- JIT testing in conjunction with the RAIC controller is an integral part of the final product.

JIT Testing VS Self-Checking Components

- JIT testing mechanisms are part of the RAIC controller.
- Self-checking mechanisms are part of the component.

Component State Recovery

- Snapshot-based
- Invocation-history-based
  - Method properties
  - Invocation history trimming
- Could be enhanced with component dependency information

[Liu, Richardson (2002)] ICSE02/CBSE5.

Related Work

- Barga and Lomet: Phoenix
- Cook and Dage: Hercules
- S. S. Yau and R. C. Cheung: Self-checking software

Conclusions

- Dependability-through-redundancy can be achieved by adopting the RAIC architecture style.
- Just-in-time component testing and component state recovery techniques support RAIC to achieve the above goal.