

PLOS17

Annotations in Operating Systems with Custom AspectC++ Attributes

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- ≈ 100 compiler-specific attributes
- Standard does not specify custom annotations or custom attribute behaviour

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 - Transforms AspectC++ to C++
 - supports arbitrary C++-compatible backend compilers, including clang and g++
- Discussion of use cases of custom annotations in OS development

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- 1 Introduction
- 2 AspectC++
- 3 Examples
 - Portable Compiler Attributes
 - Operating System APIs
 - Source Code and Model Co-Development
- 4 Discussion

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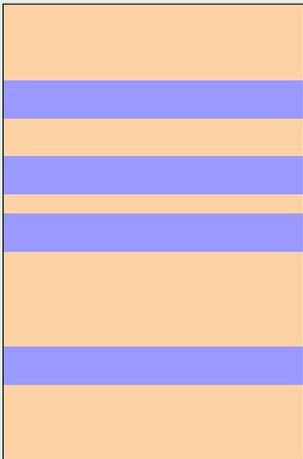
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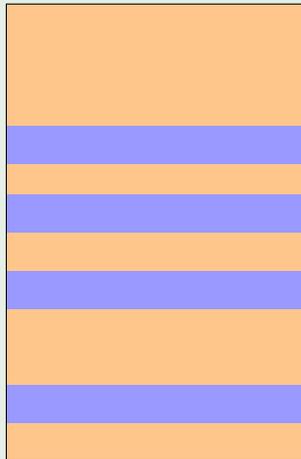
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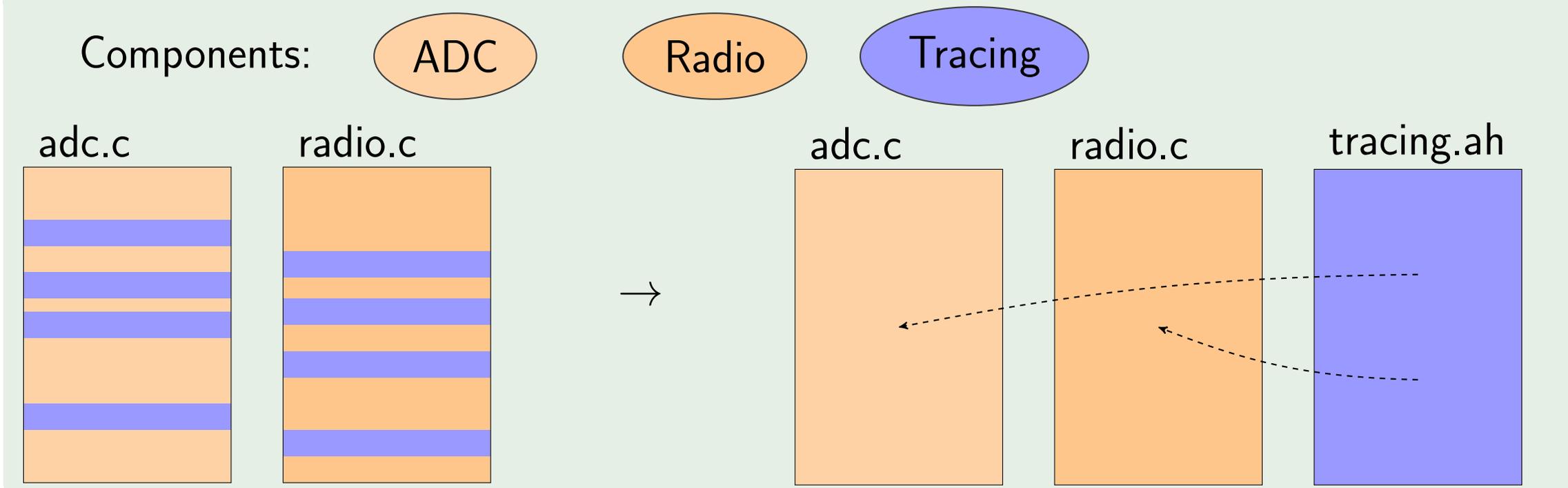
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Aspect-Oriented Programming (AOP)

- AspectC++ is a C++ extension for AOP [SL07]
- Aspect: piece of code affecting (many) other system modules

Example (Function call tracing)



- Tracing code is **woven** into ADC and radio

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advice execution(tracing::call()) : before() {
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- Developers **express intentions** by annotating code fragments
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- Limitation: Cannot affect code generation by compiler
 - Custom attributes cannot set alignment, binary sections, ...

Operating System APIs

- Annotations can also **describe behaviour** and serve as API

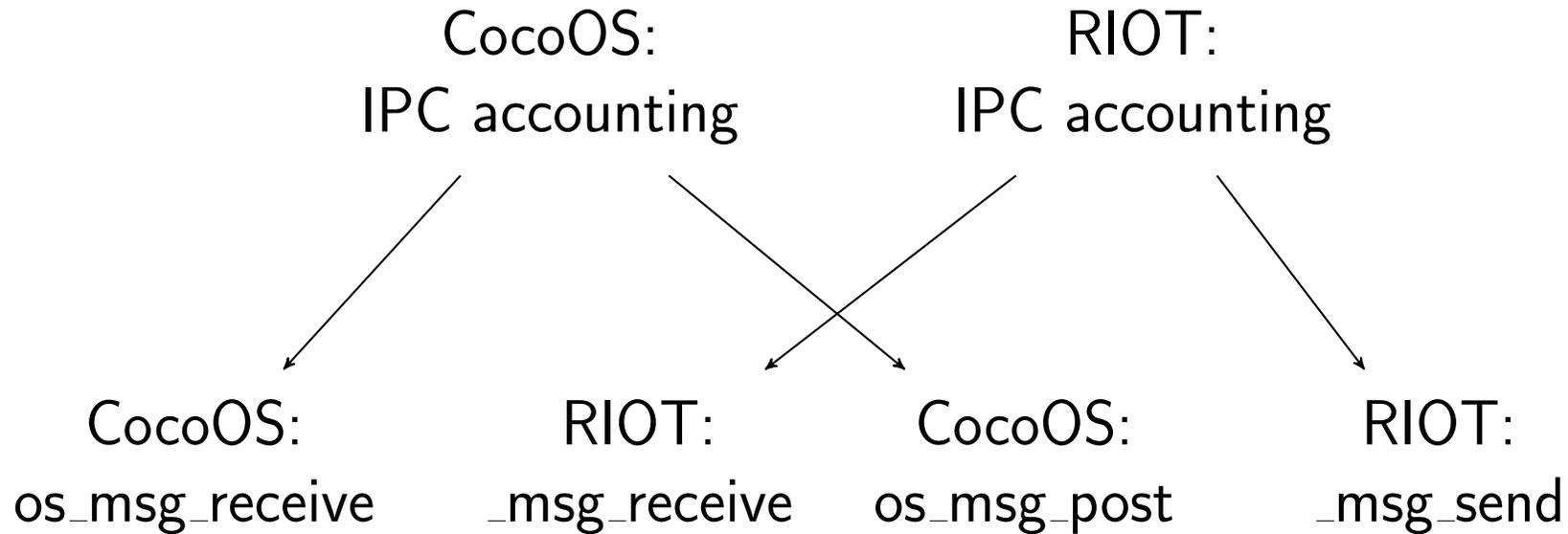


Figure: Interfacing with system components

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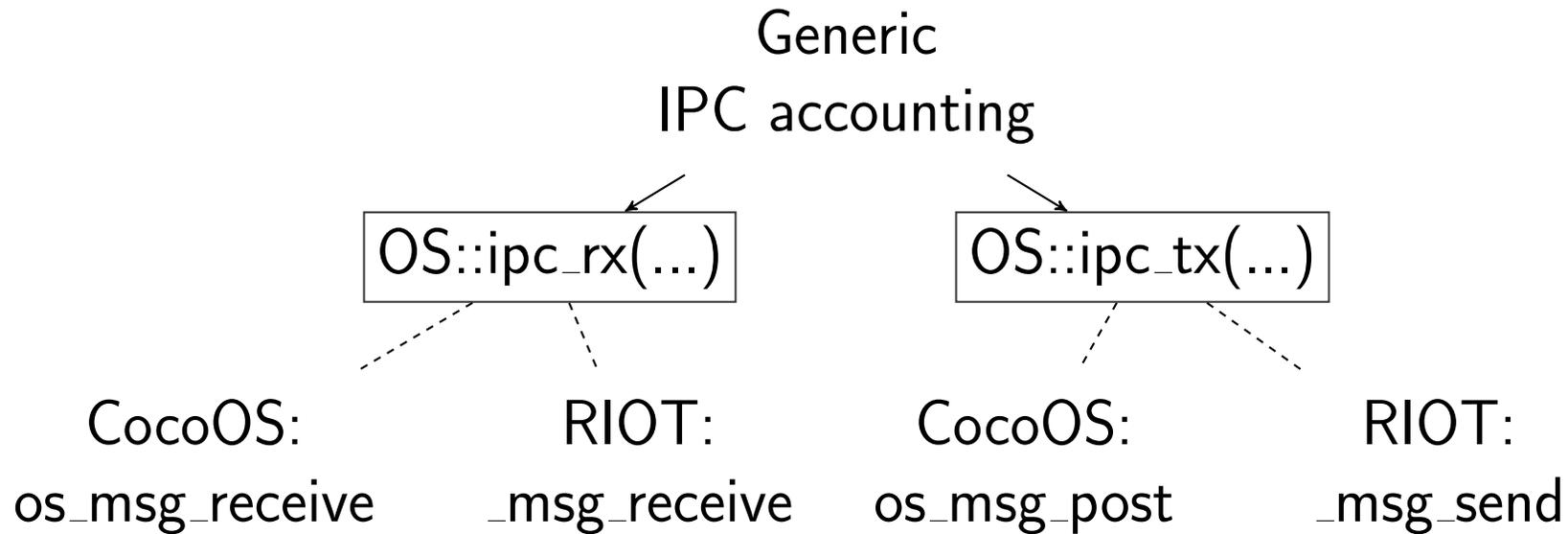


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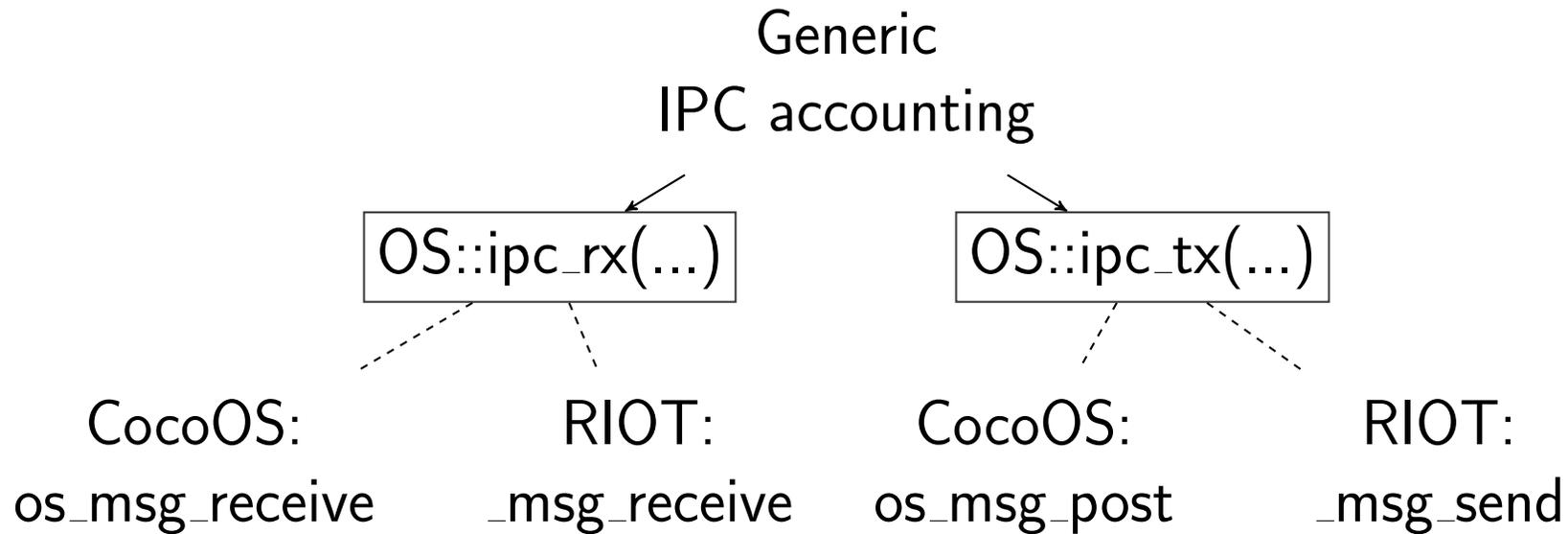


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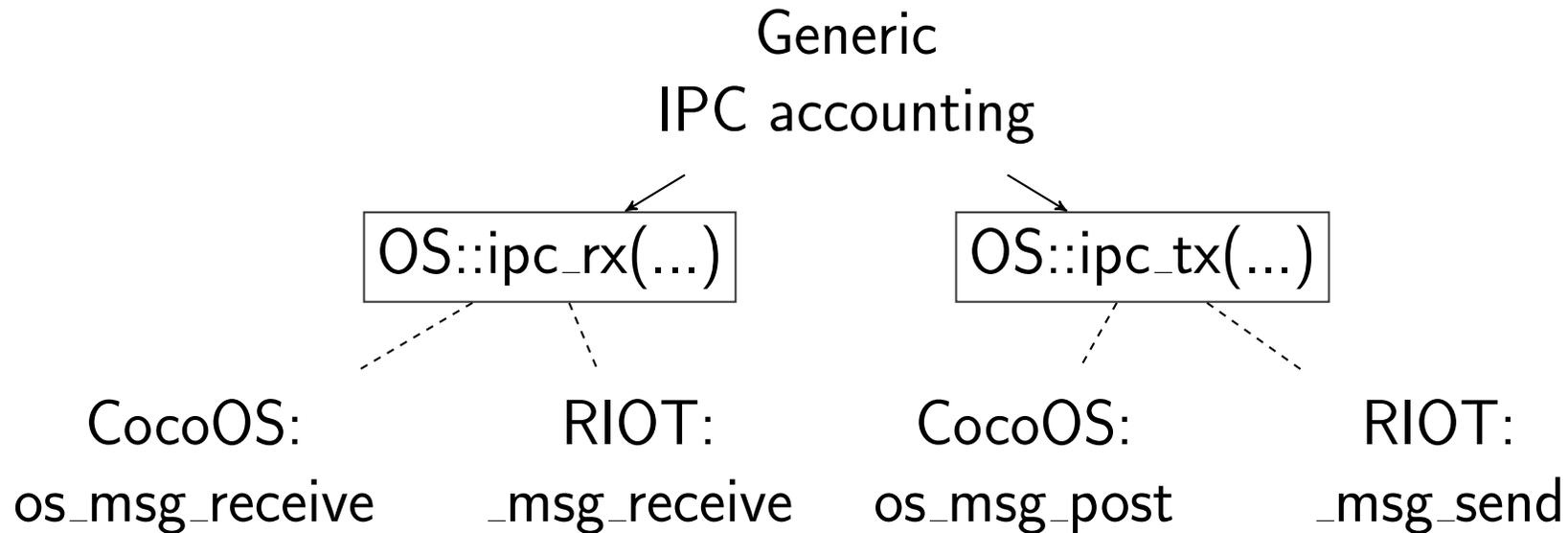


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 - Details (parameter holding IPC message length, ...) can be specified via attribute parameters
 - Additional machine-readable documentation layer

Plugins for System APIs

- Modules can hook into annotation API
 - System provides annotated function stubs or default implementation
 - Modules use attribute advices to replace them

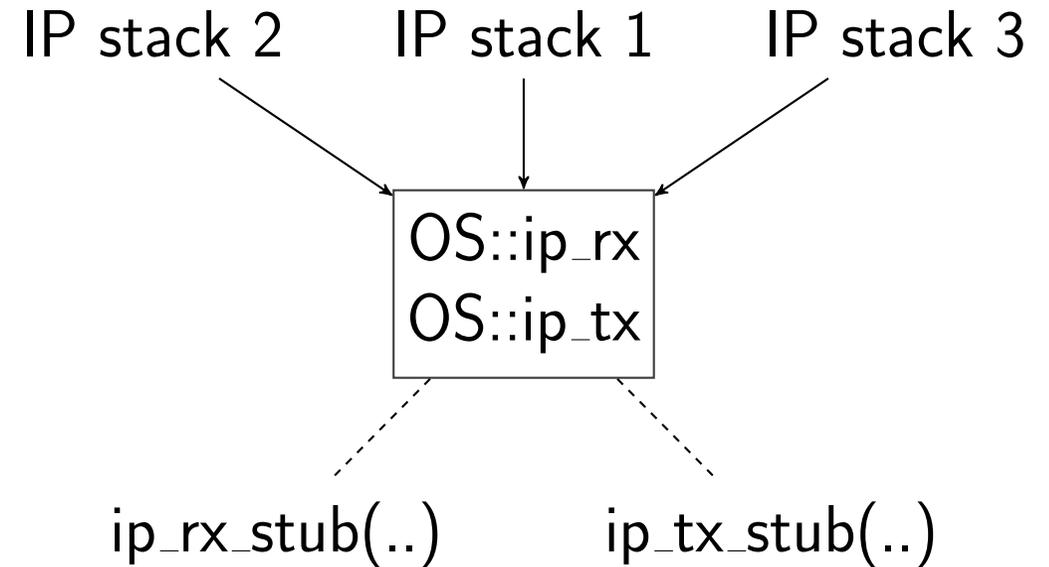


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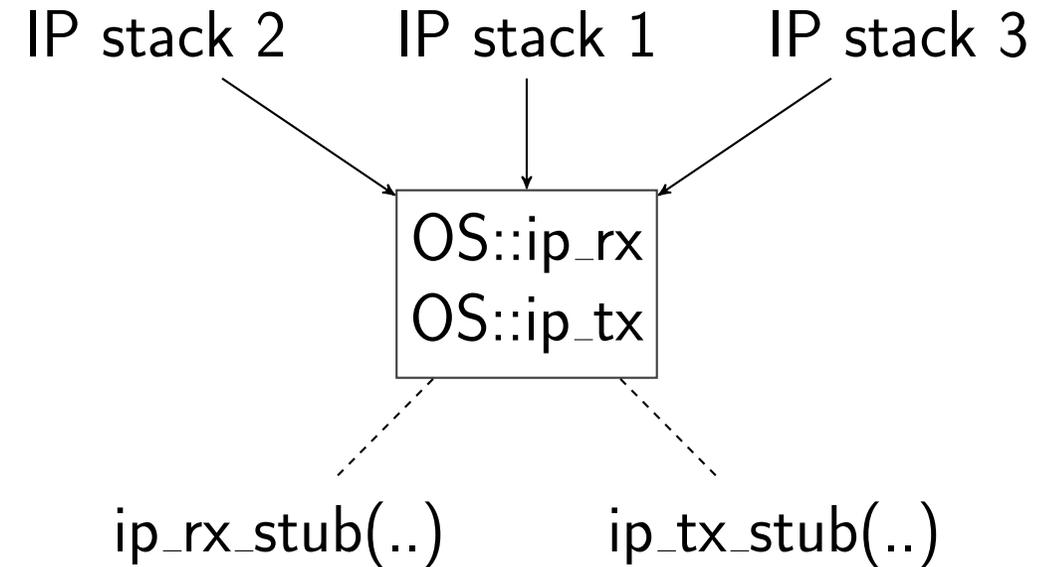


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- Modules need to match annotations
 - Moves adaption responsibility from system to modules
 - Helps writing clean system code

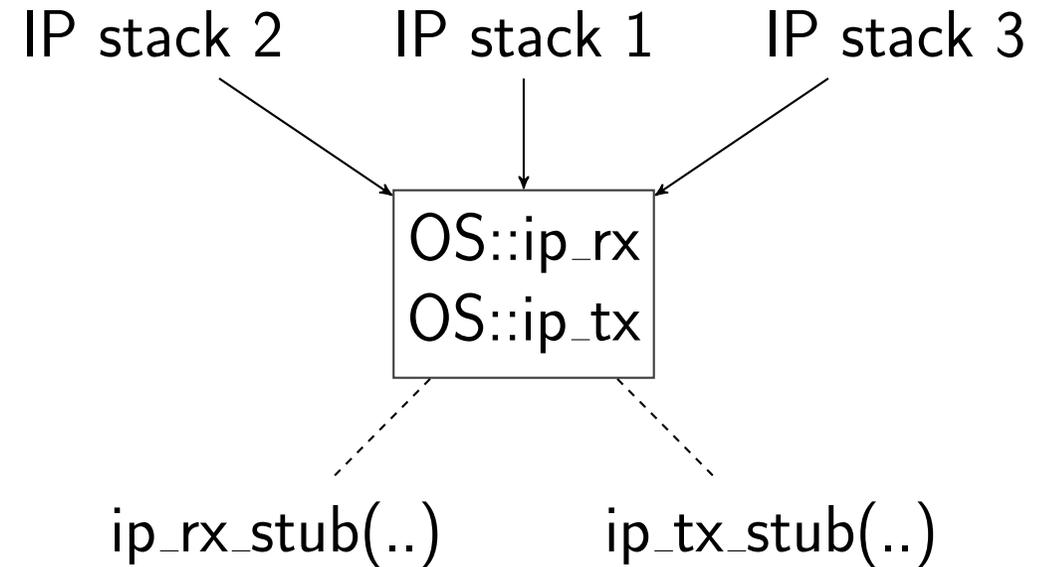


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void disable(); void enable();  
int send(char *data, u8 len);  
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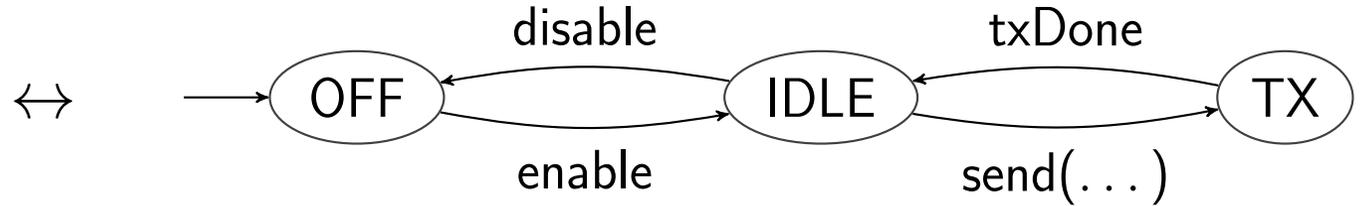


Figure: Simplified model for a radio driver

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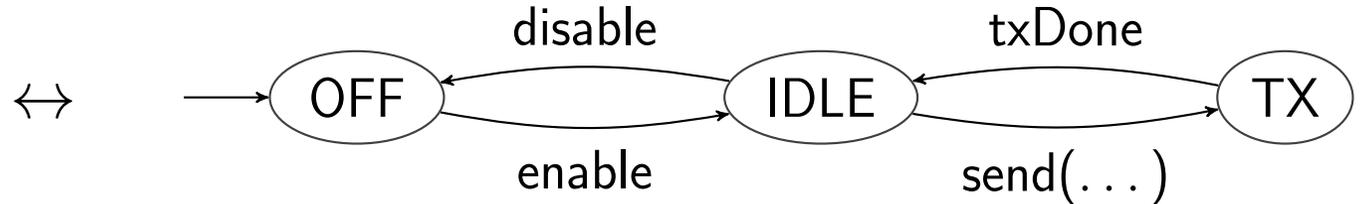


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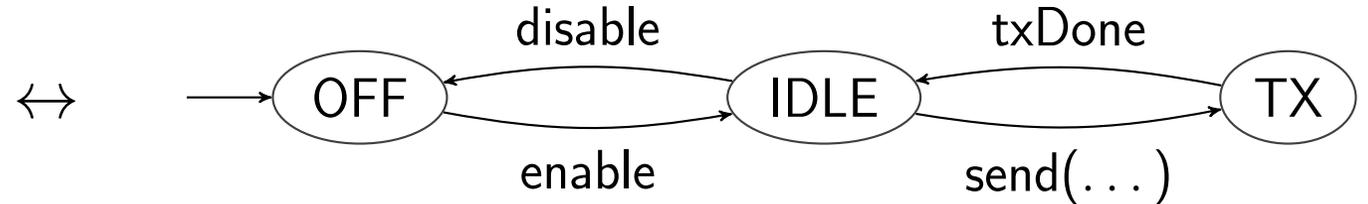


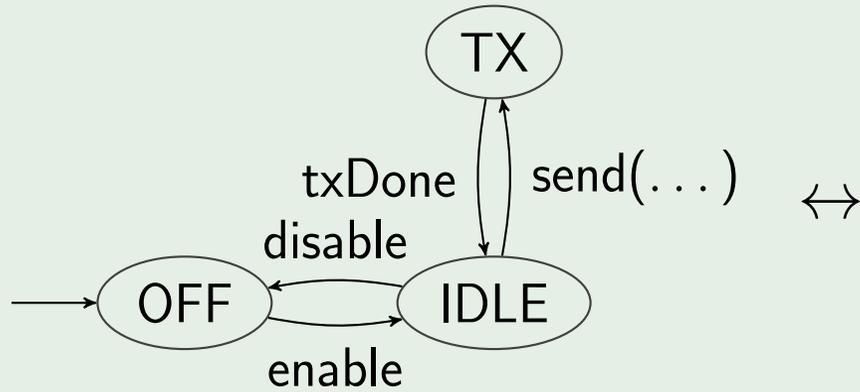
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- Challenge: synchronization model \leftrightarrow code
 - Model driven development addresses model adjustment \rightarrow implementation update
 - But: implementation may evolve \rightarrow model needs update
 - model inference from source code rarely captures entire model [GSB09]

Source Code and Model Co-Development

- Attributes allow embedding models into source code

Example



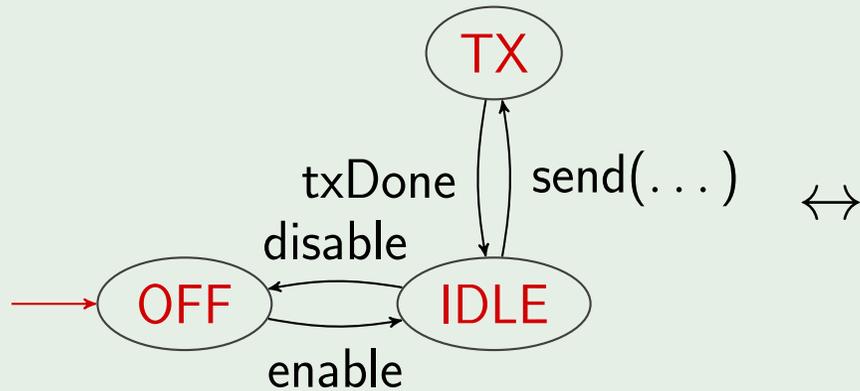
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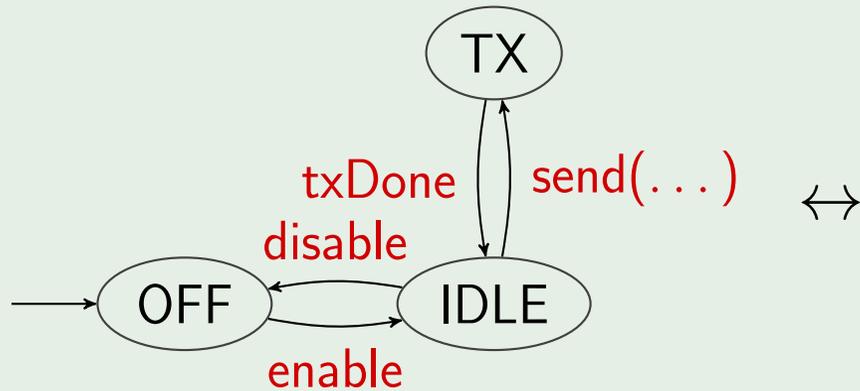
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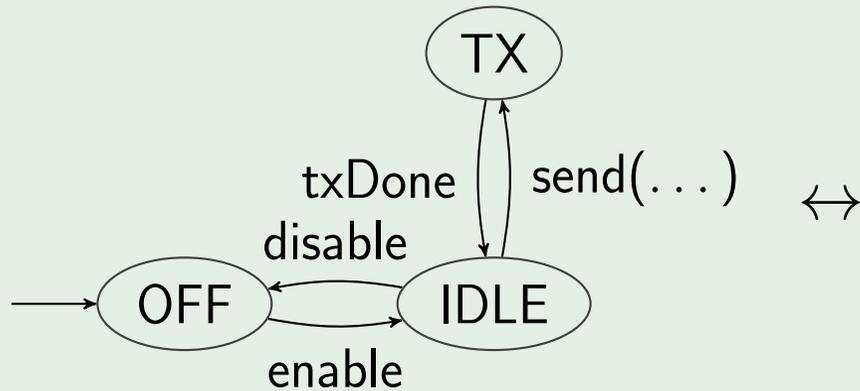
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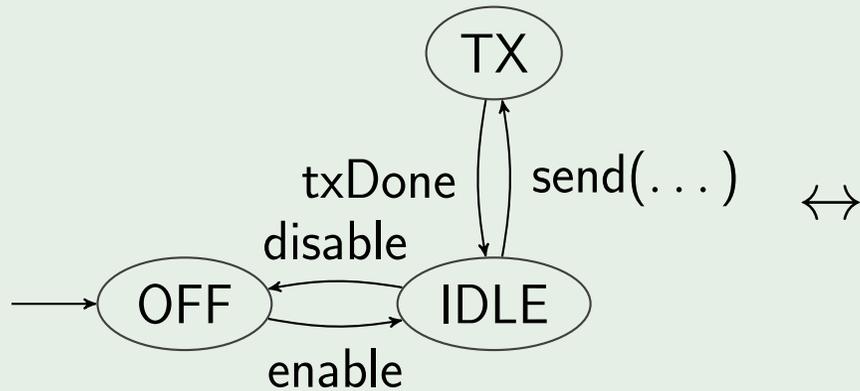
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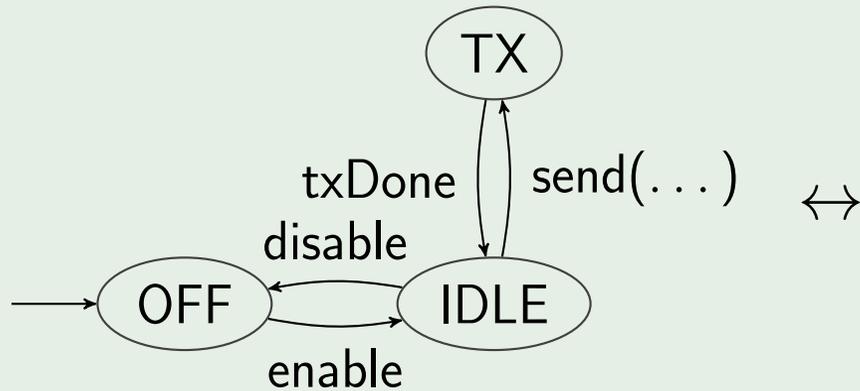
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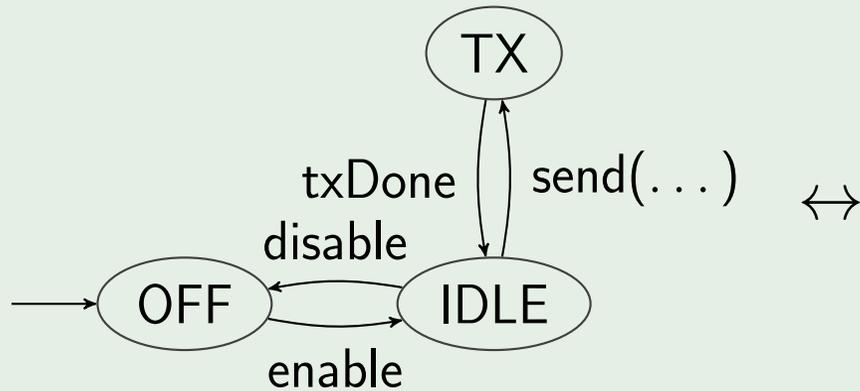
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- Works for arbitrary DFA-based models
- Model next to implementation → easy to update
 - Pre-existing code can be extended with models and re-used
- Can be made (partially) available at runtime by aspects
- Zero overhead when unused
 - Annotations can also be parsed by external tools

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- C++ source is compatible with AspectC++
 - Can be annotated and used with AspectC++ compiler
 - C++ backwards-compatibility possible with preprocessor macros
- C source needs to be adapted to C++
 - Tedious, but usually feasible
 - Depends on project size and amount of non-C++-compatible C code

Evaluation

- Examples used on three embedded OSes: CocoOS (C), RIOT (C) and Kratos (AspectC++)
 - Adaption to C++ took < 1 hour for CocoOS and one day for most of RIOT x86
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- Annotations without aspects cause zero runtime overhead
- Negligible difference between manual and annotation-based implementations
 - less than ± 0.1 % runtime size variation (assumed to be optimization corner cases)
 - No runtime aspect resolution

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- ... can provide System APIs for plugins
- ... support source code and model co-development
- ... do not cause significant code size or runtime penalties
- Similar possibilities with Java/AspectJ, Python and C#
 - Resolved at runtime → execution time overhead
 - C/C++ more common for OS development
 - AspectC++ usable with any C++-compatible backend compiler

References I

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