IntelliDroid

A Targeted Input Generator for the Dynamic Analysis of Android Malware

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Static vs. Dynamic Analysis

- Static analysis: analyze source code or byte code
  - Imprecise
  - No run-time data
- Dynamic analysis: analyze during execution
  - Run-time values → precise

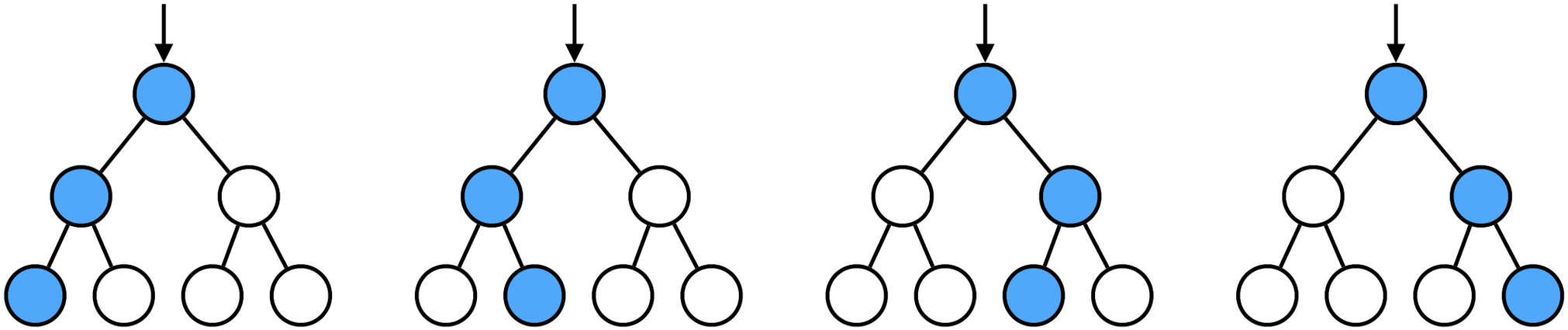
Dynamic Code Coverage

- To detect malicious activity, first have to execute it
- Example:

```
message = <receive confirmation SMS>
if message.number == ‘1234’:
    <malicious action>
```

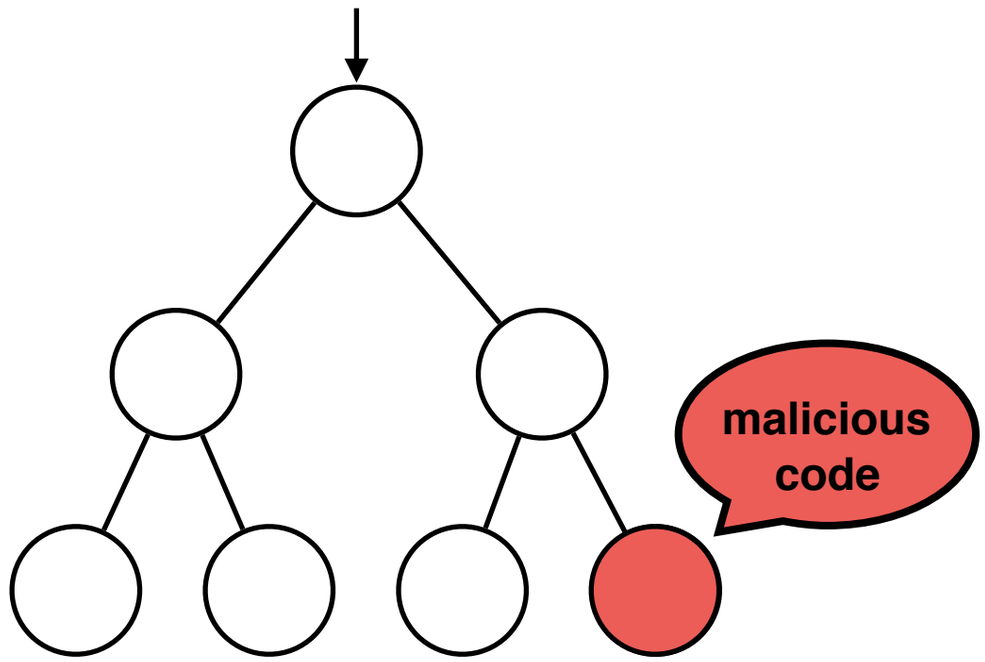
Concolic Testing

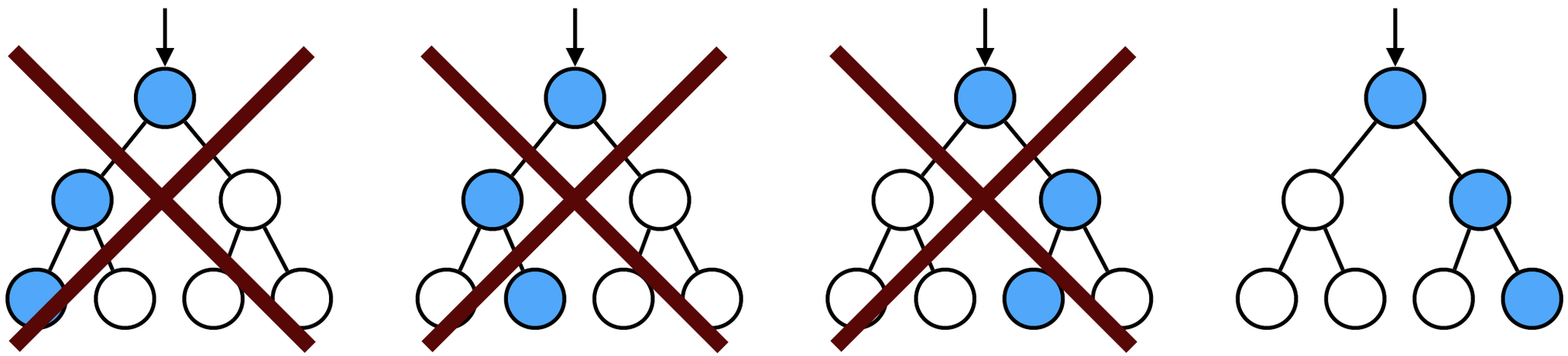
- Run all execution paths in application
- Symbolic execution, solve constraints for inputs



Specific Malicious Paths

- Malicious activity only executed in certain parts of the code



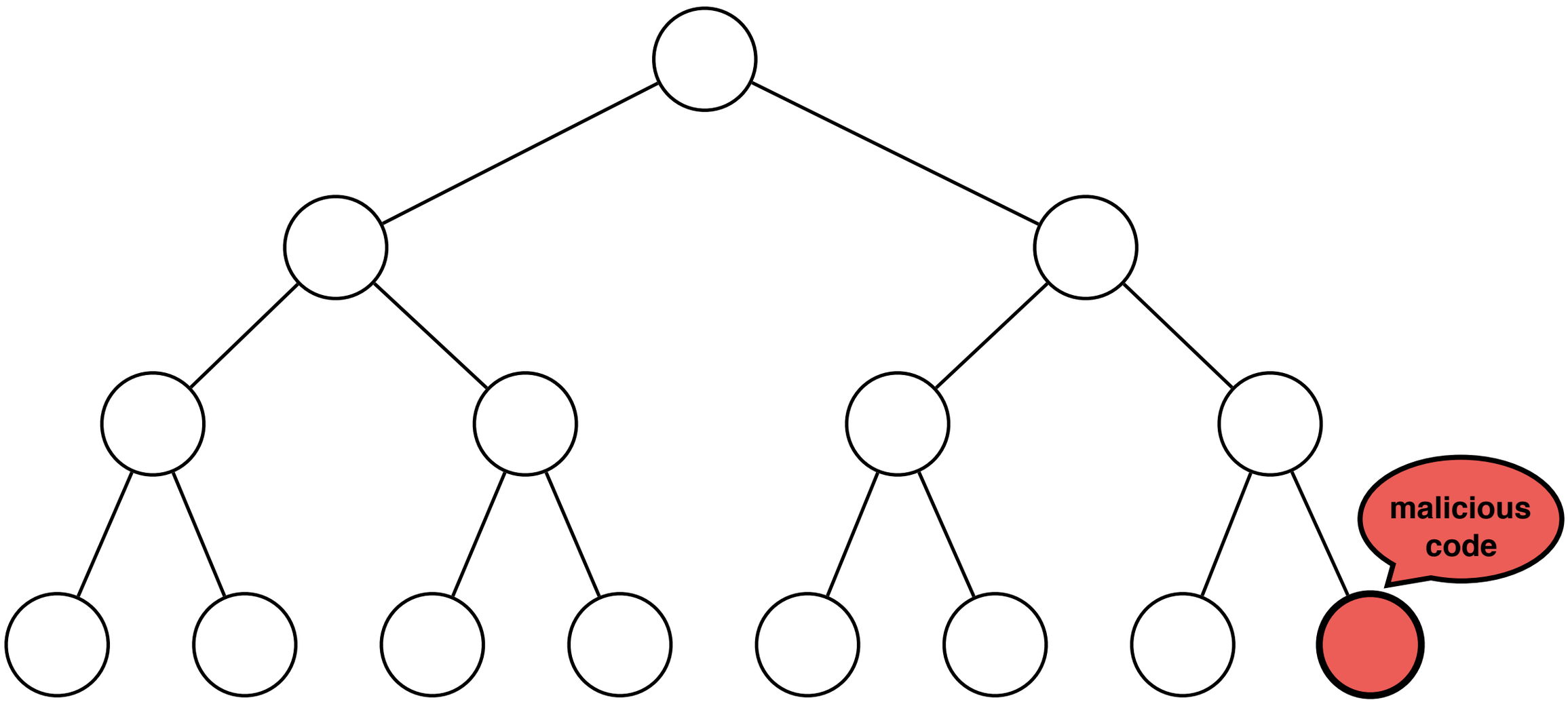


IntelliDroid

- Targets specific parts of the application
  - Input generator for existing dynamic detector
  - Hybrid static and dynamic design
- Implemented for Android
- Improve malware analysis and detection

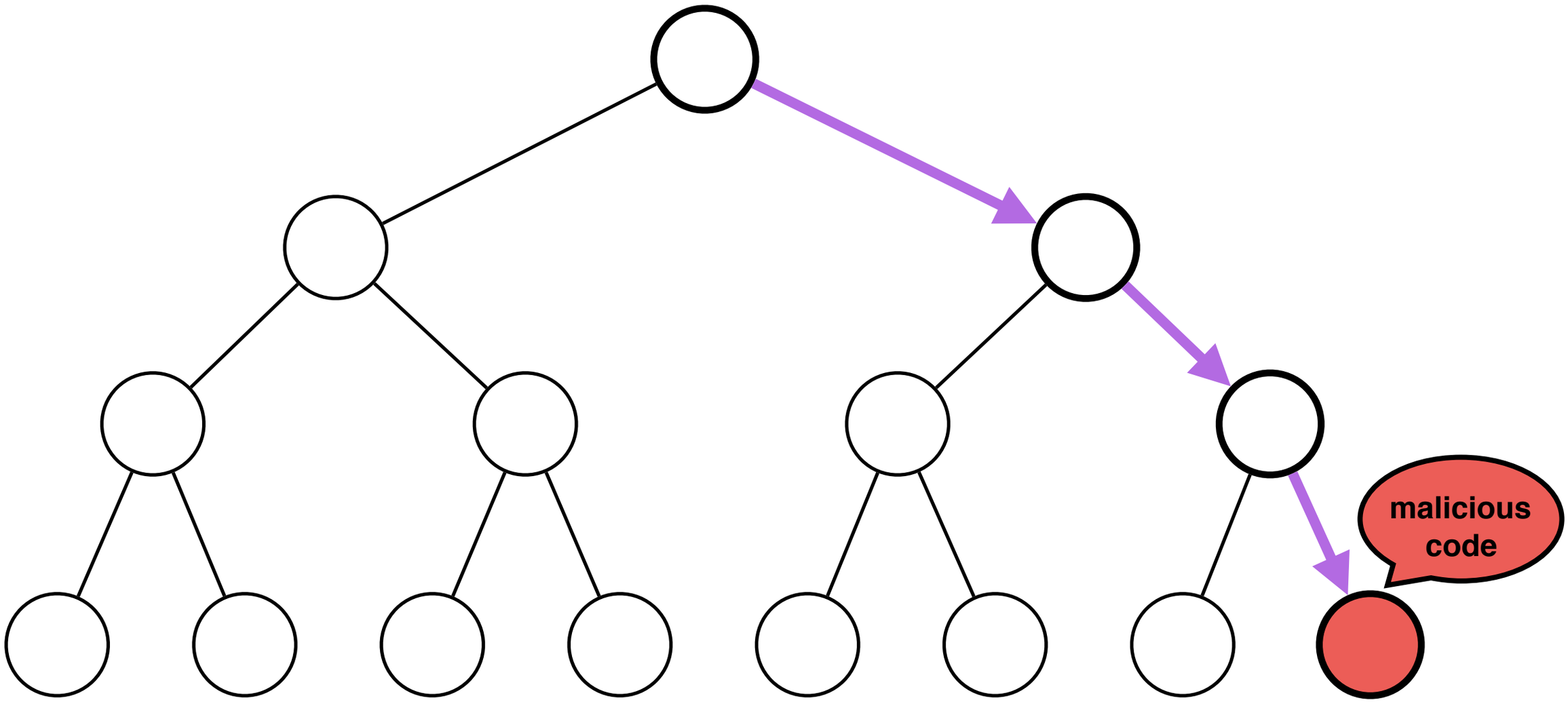
Target Malicious Paths

- Malicious activity present only in certain parts of the code



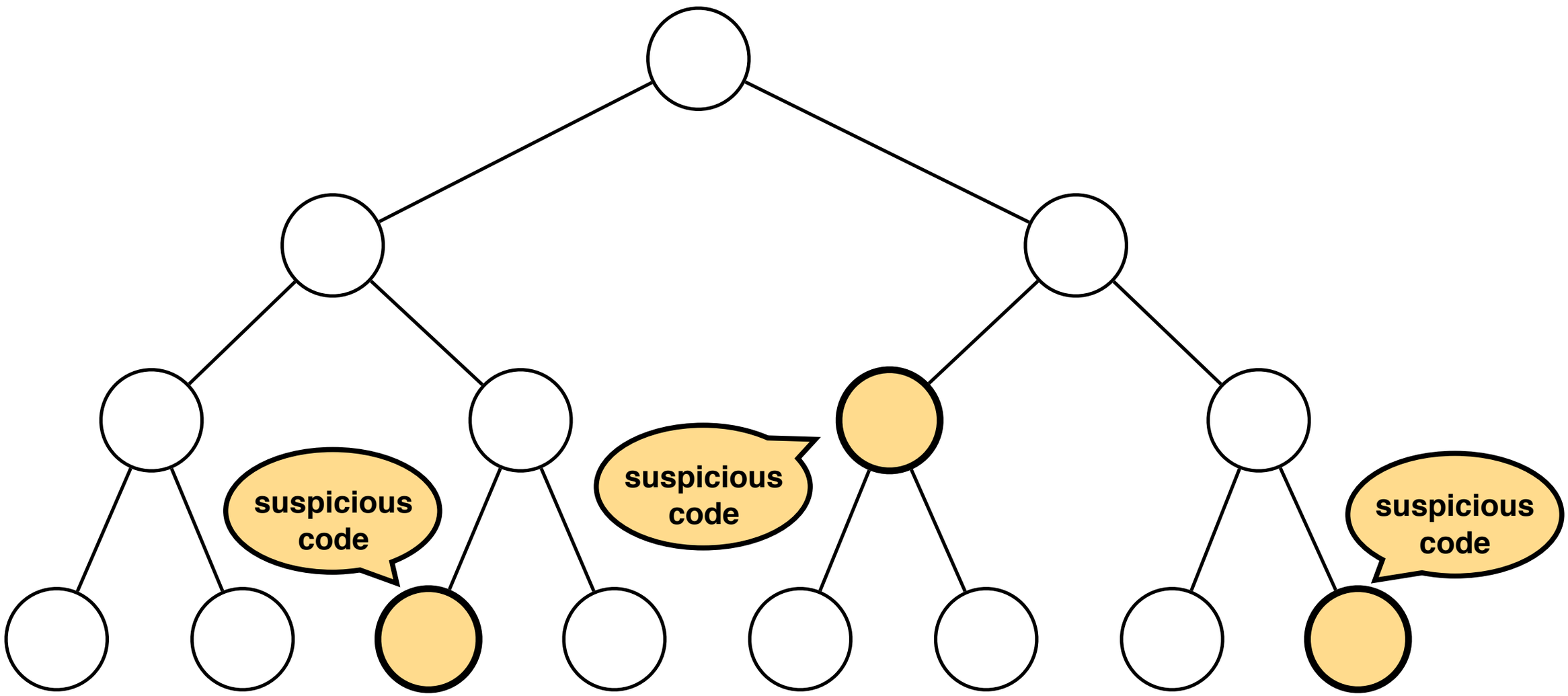
Target Malicious Paths

- Use static analysis to look for call paths to malicious activity



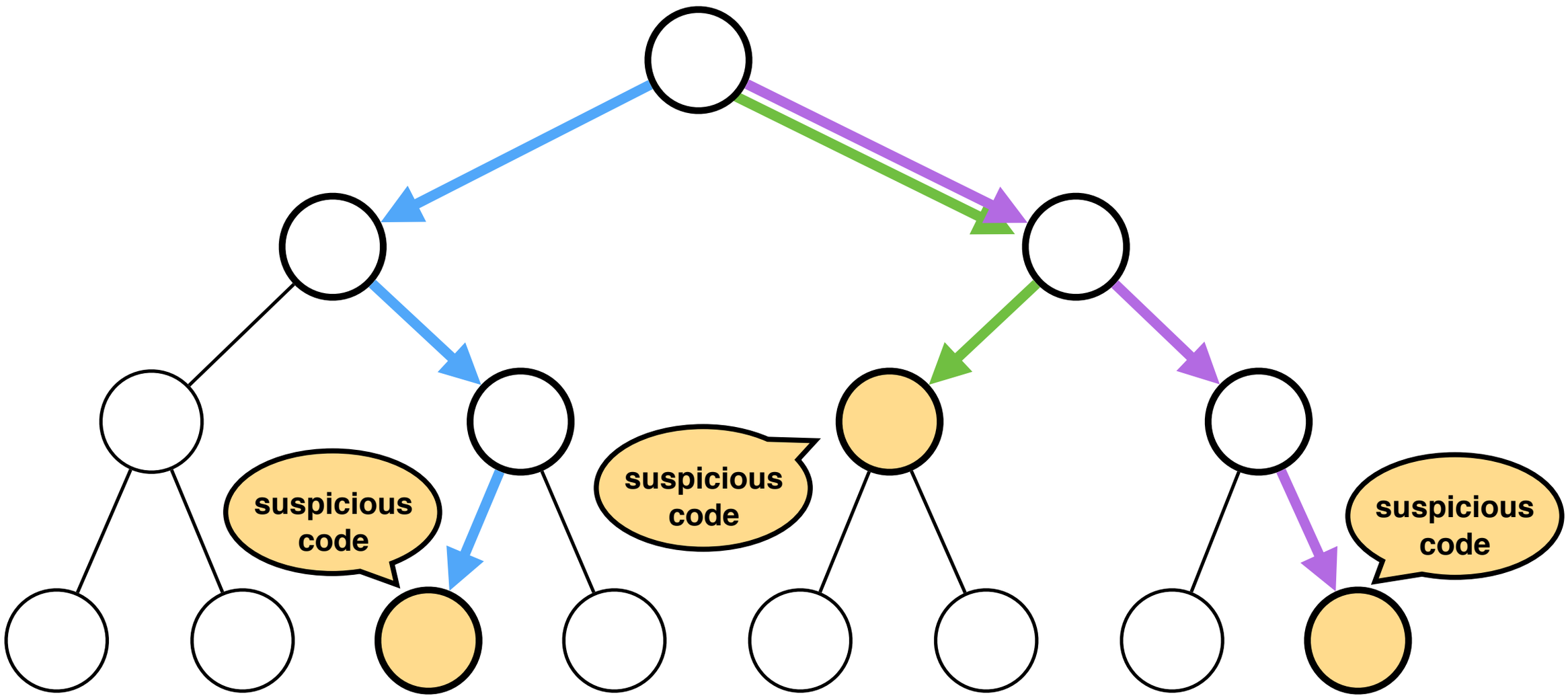
Target Over-Approximation

- Target over-approximation of malicious behaviors



Target Over-Approximation

- Target over-approximation of malicious behaviors



Targeted Methods

- Use method invocations as over-approximation
  - Depends on attached dynamic malware detector
- Existing dynamic detectors for Android:

✔ Method invocations

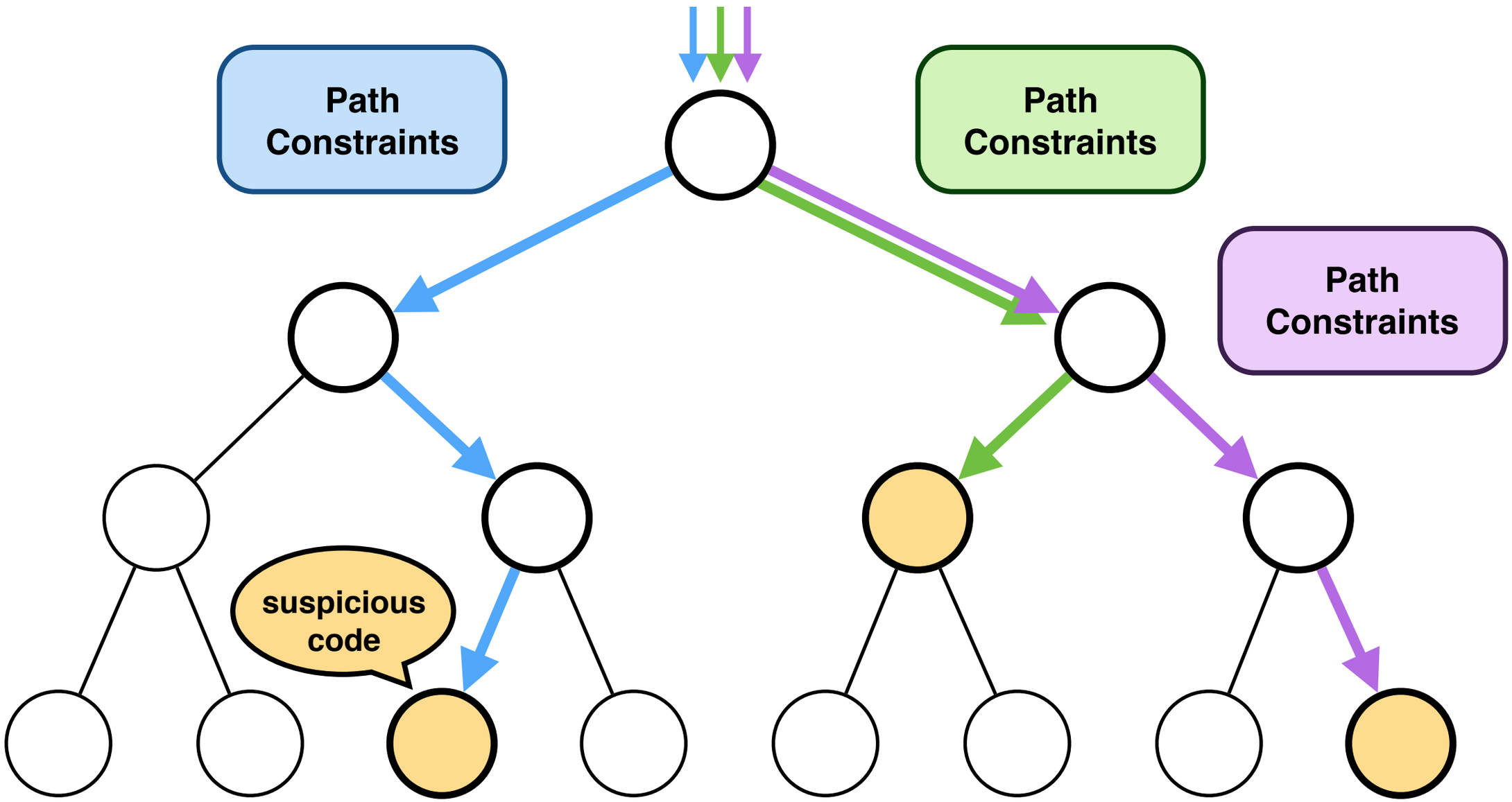
✔ System call traces

✘ Anomaly detection

Dynamic Tool	Goal	Features for Analysis
AASandbox [10]	Monitor behavior via tracking of system calls	System calls
Andromaly [36]	Malware detection via system resource usage	Low-level device features (e.g. battery usage, CPU load)
CopperDroid [39]	Monitor behavior via system call tracking	System calls
Crowdroid [12]	Monitor behavior via tracking of system calls	System calls
DroidBox [18]	Sandbox to monitor external accesses	Sink API methods
DroidRanger [50]	Detect malware using pre-specified behavioral footprints and heuristics	Sequence of API method invocations and parameters
DroidScope [39]	Plugins for API tracking, instruction tracing, and taint tracking	API methods; source/sink API methods
RiskRanker [39]	Detect malware using known vulnerability signatures	Sequence of API method invocations
TaintDroid [19]	Detect privacy leakage	Source/sink API methods
VetDroid [47]	Malware detection via permission use behavior	Permission requests (can be mapped to API methods)

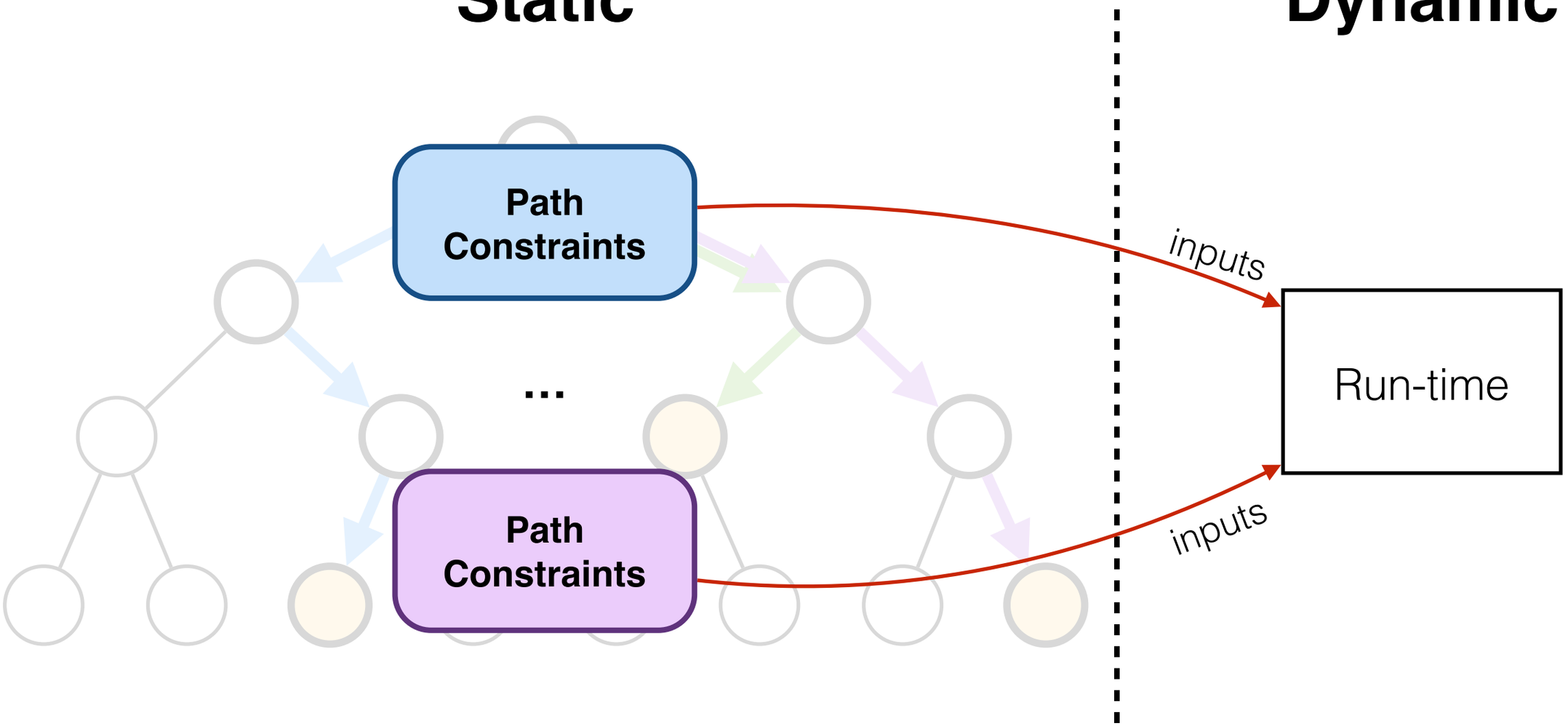
Static Constraint Extraction

- Extract constraints on inputs that can trigger targeted paths



Targeted Input Injection

- Inject constrained inputs to execute paths at run-time



Challenges

- Finding targeted paths using static analysis
  - Imprecision?
- Executing path to suspicious code
  - Dependencies between paths?
- Run-time input injection
  - Where to inject?

Static Imprecision

- Static analysis cannot determine run-time values
- Example:

```
message = <receive confirmation SMS>
if message.number == <file A>.text:
    <malicious action>
```

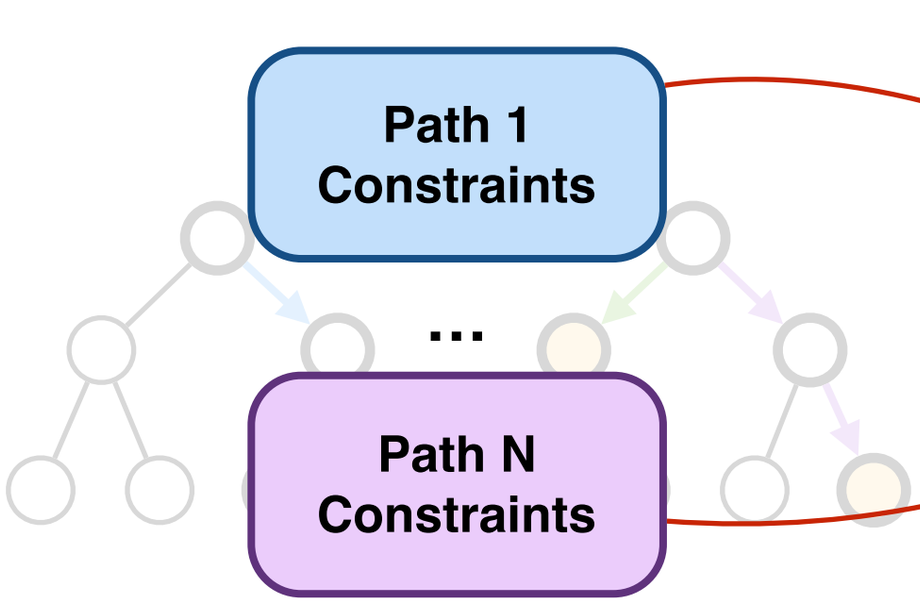
Constraint

<SMS message>.number == <file A>

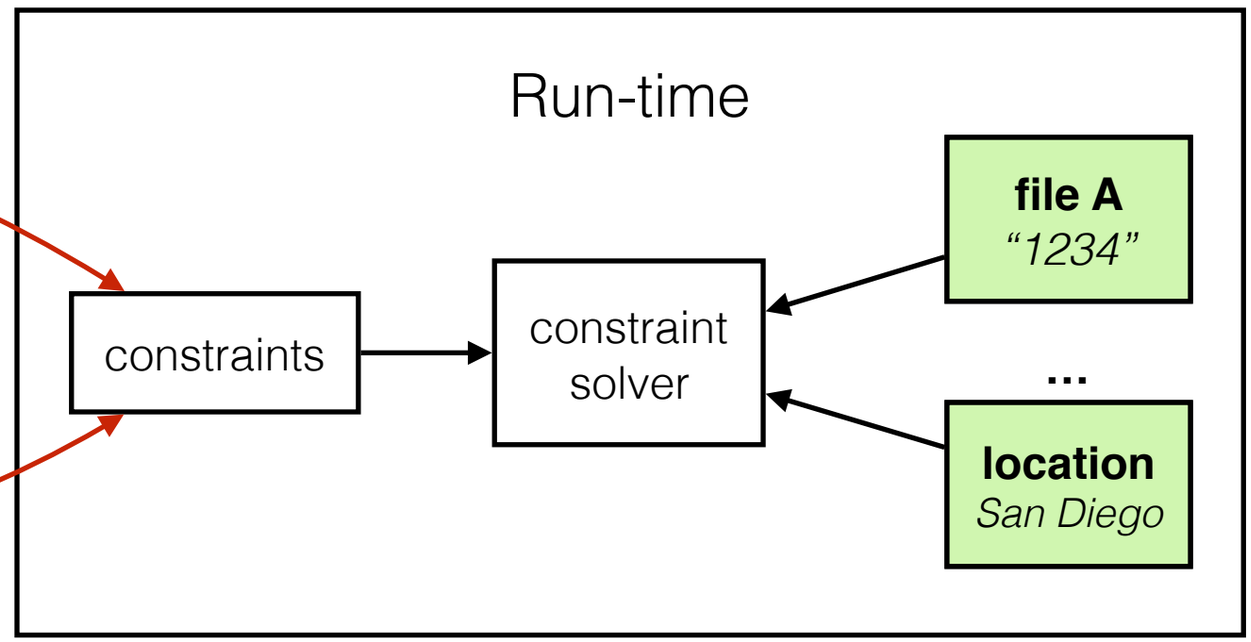
Using Run-time Data

- Solve constraints at run-time (with run-time data)

Static



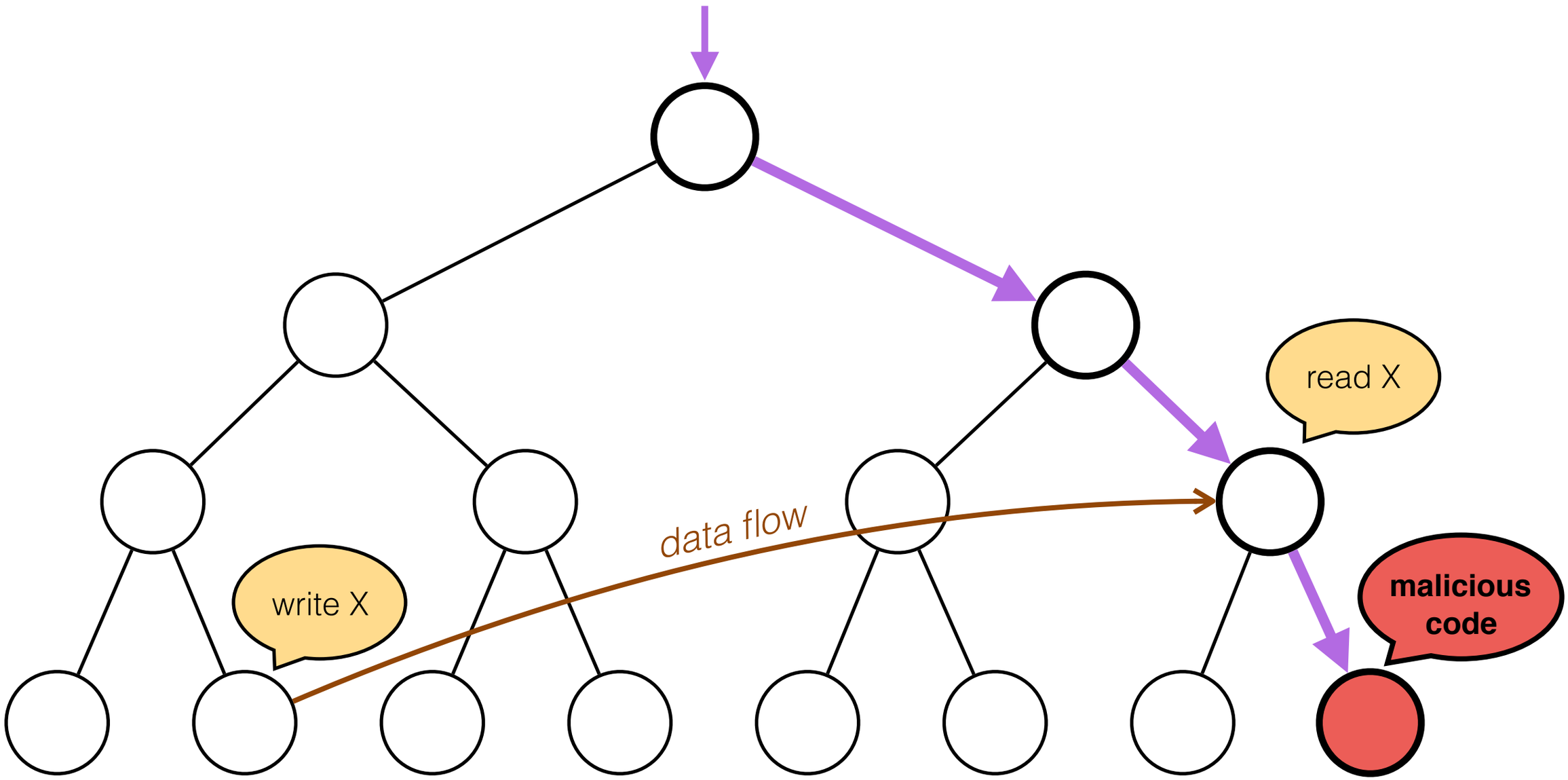
Dynamic




```
<SMS message>.number == "1234"
```

Path Dependencies

- Data- and control-flow dependencies between call paths



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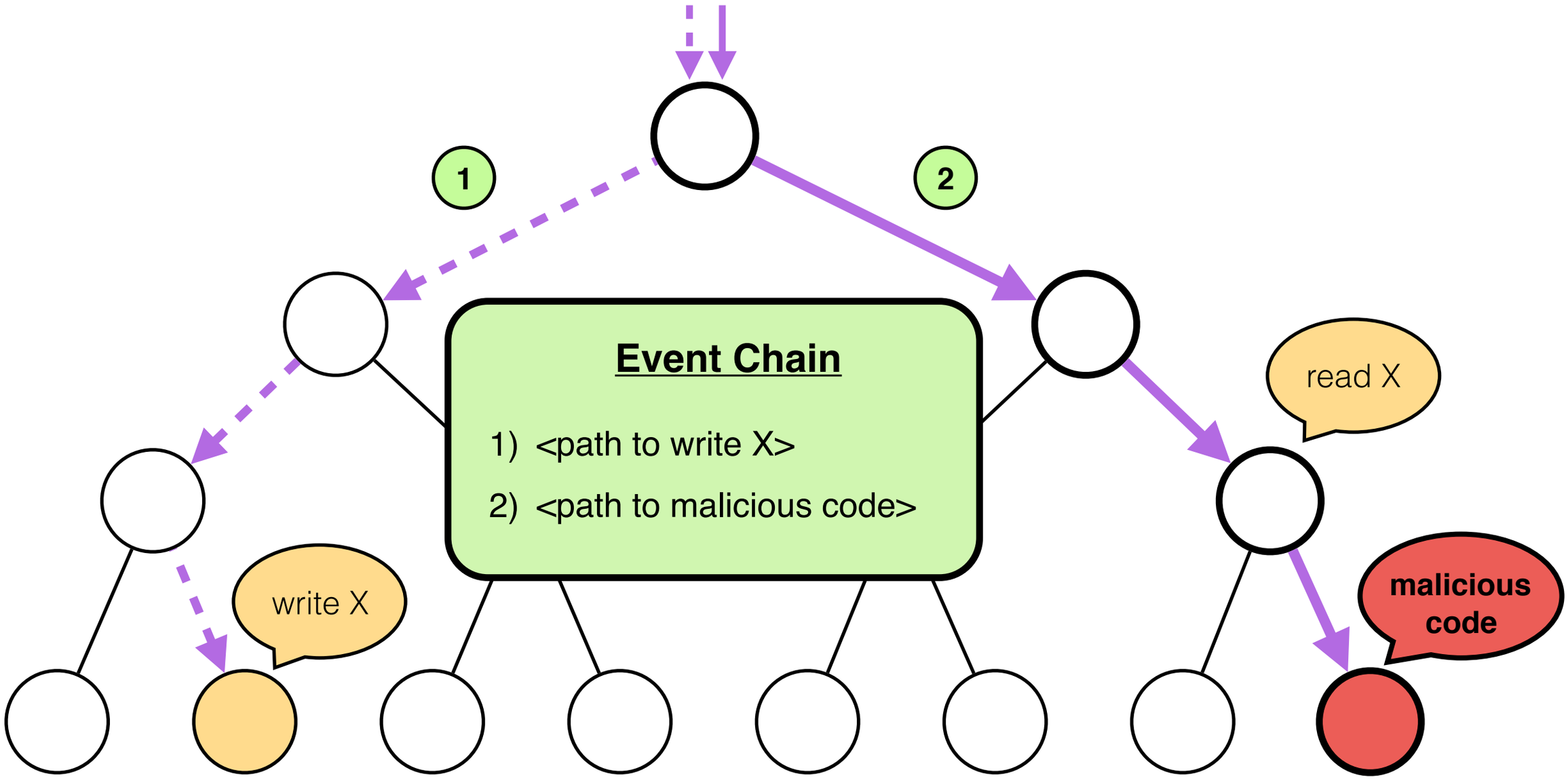
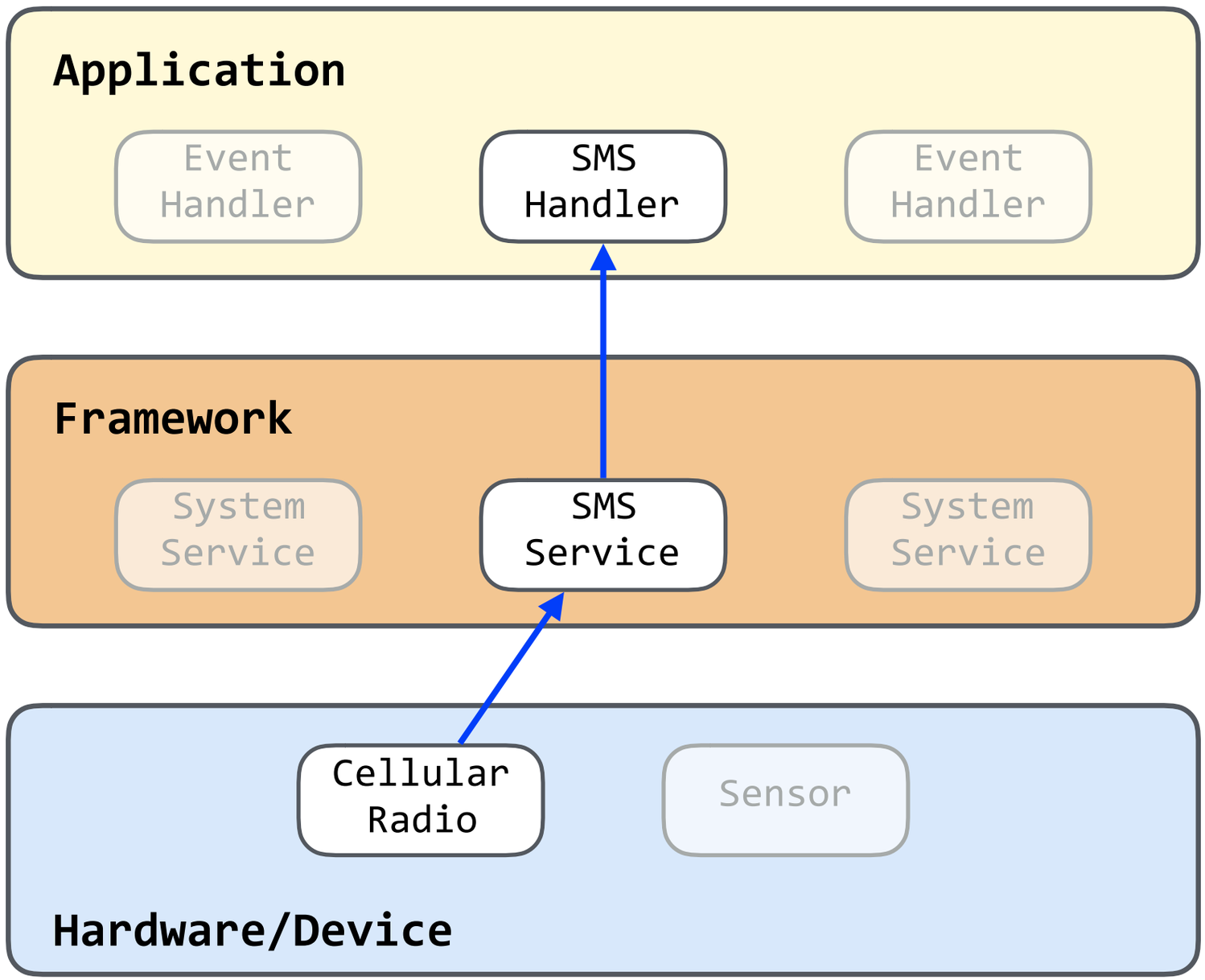
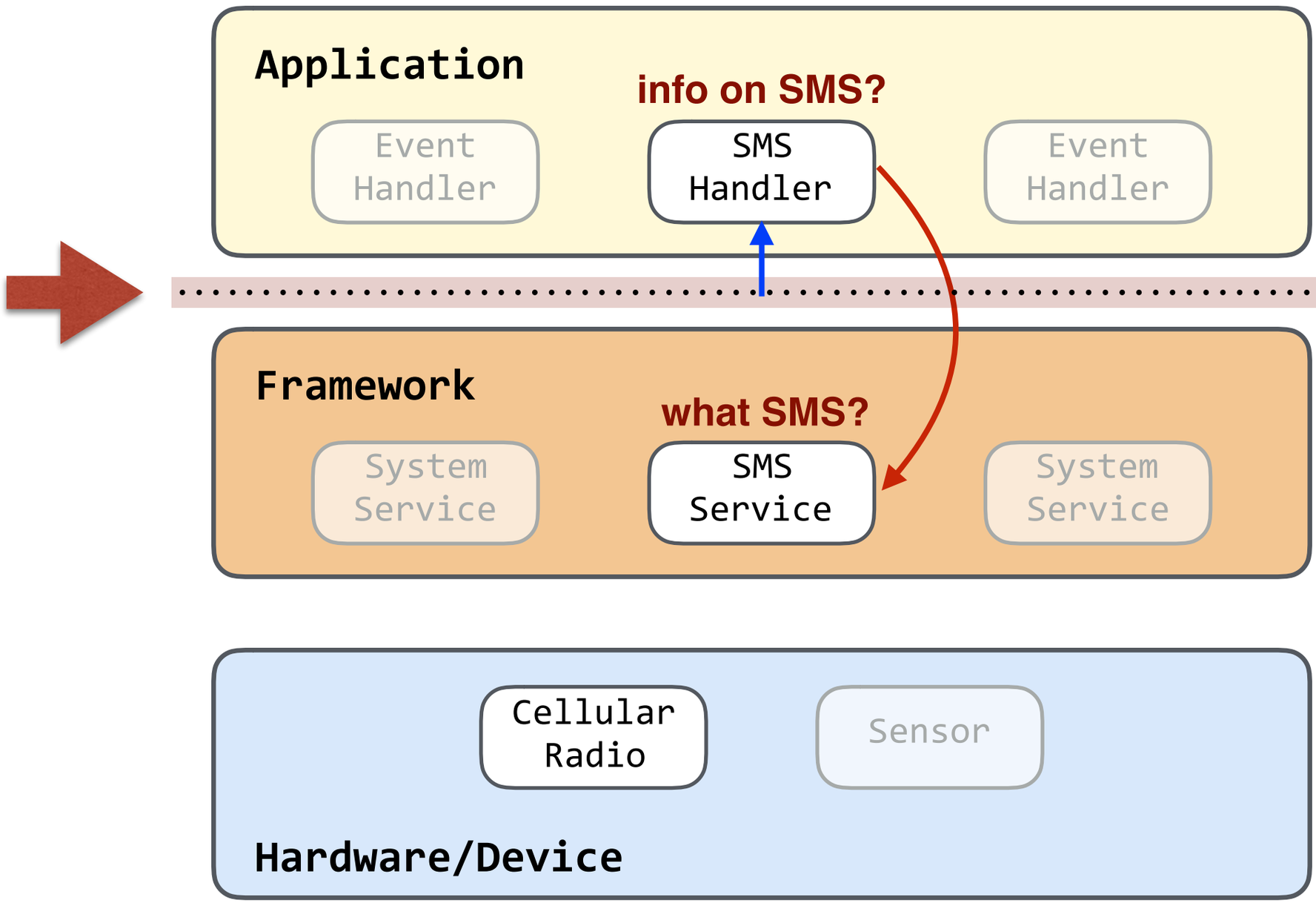


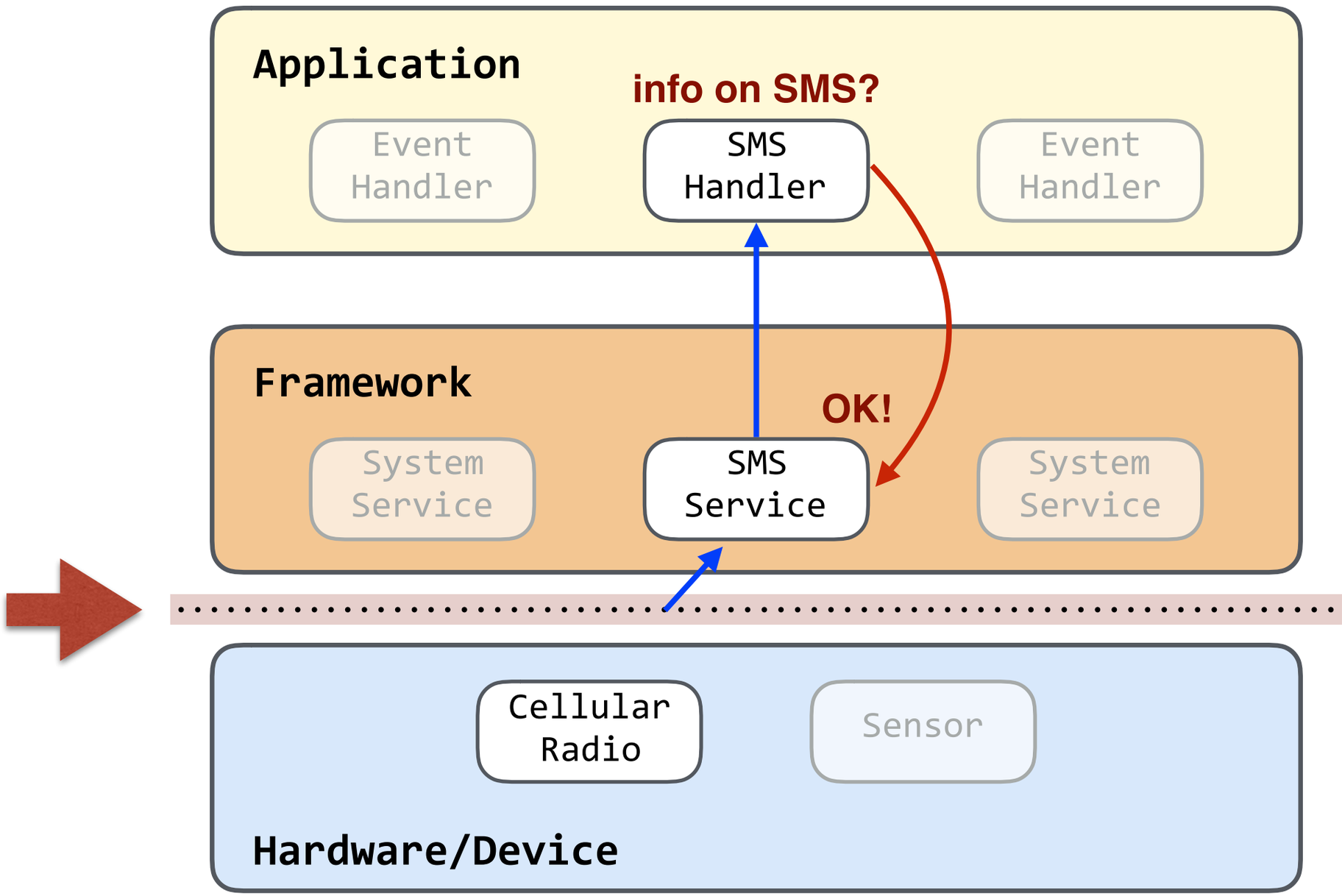
Run-Time Injection



Application Injection



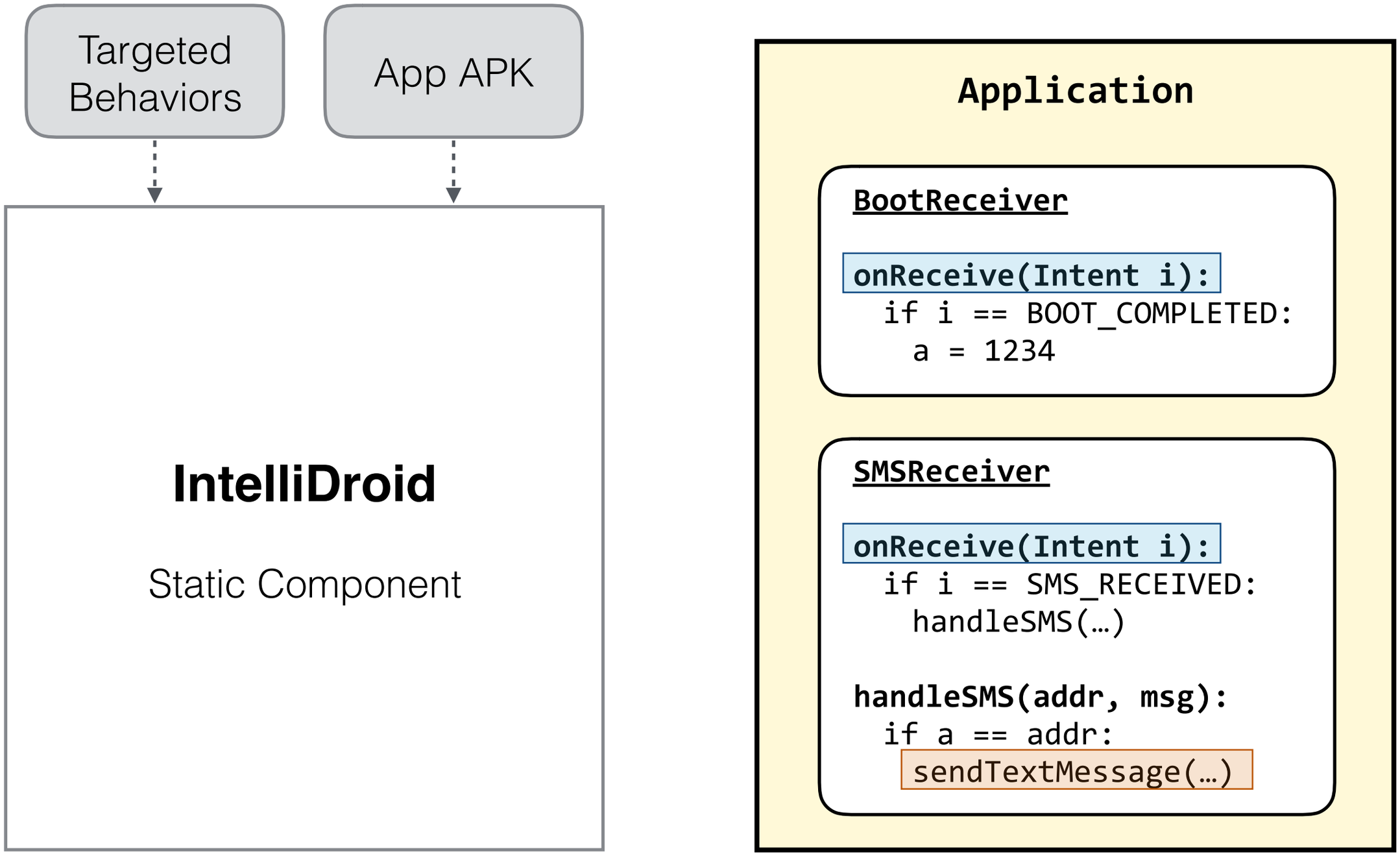
Device-Framework Injection



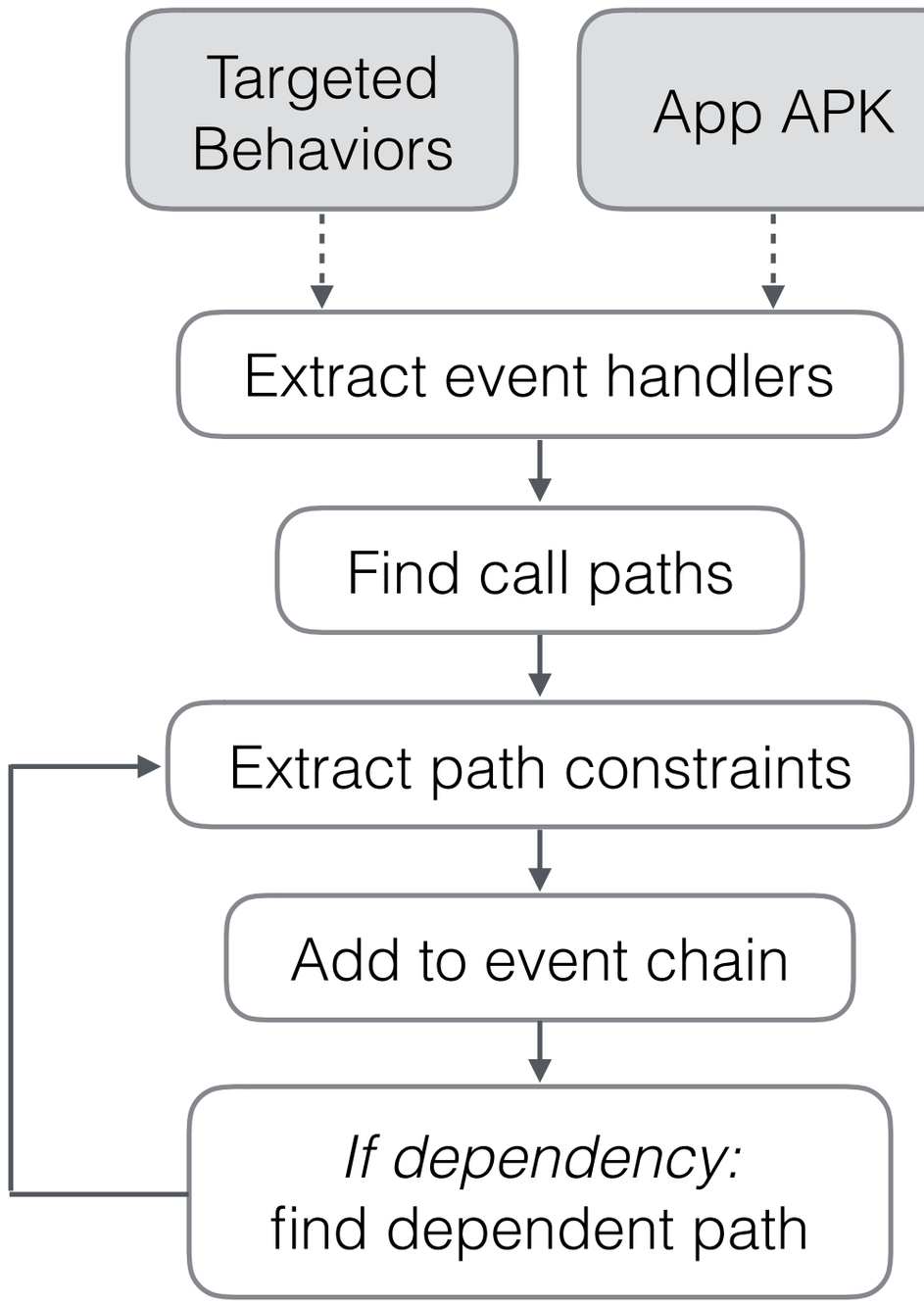
Contributions

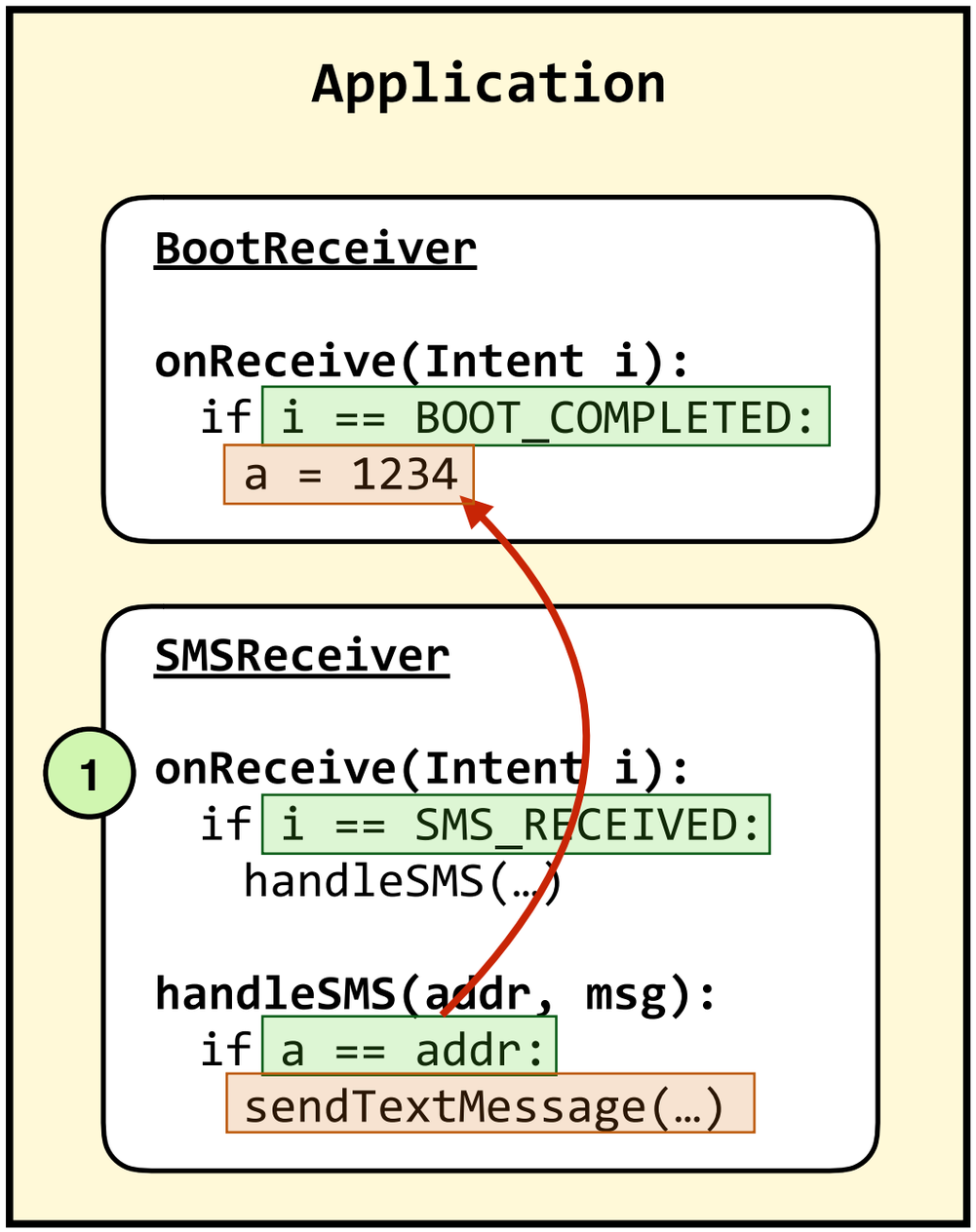
- Static imprecision
  - Dynamic constraint solving with run-time values
- Path dependencies
  - Event chains
- Consistent input injection
  - Device-framework injection

Static Component

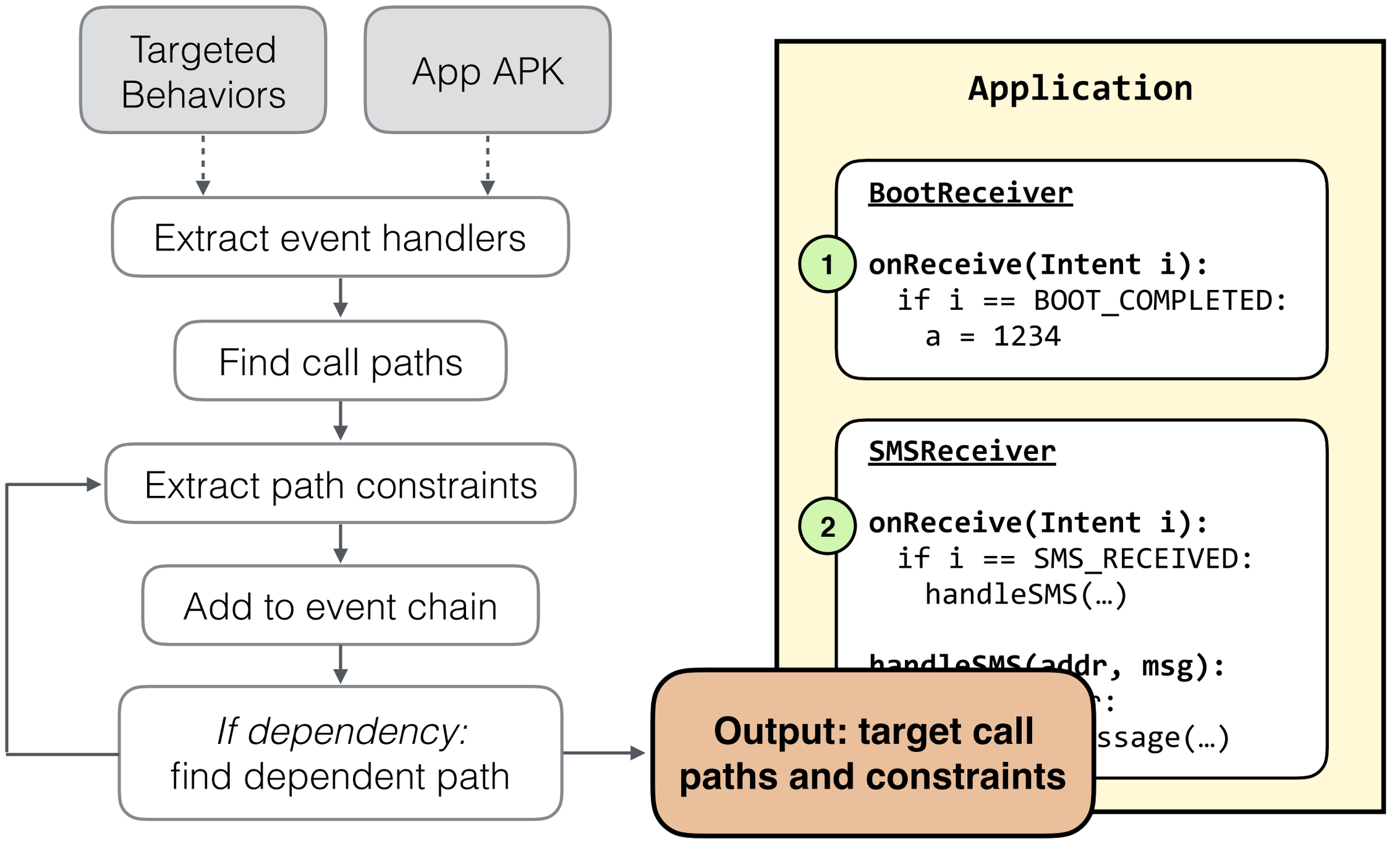


Static Component





Static Component



Implementation

- Static analysis (Android-specific): WALA [1]
- Dynamic component:
  - Client program (Python)
    - Constraint solver: Z3 [2]
  - Custom Android OS
    - `IntelliDroidService`: system service to receive input information and inject events

[1] Watson libraries for analysis. http://wala.sourceforge.net. Accessed: September 2014.

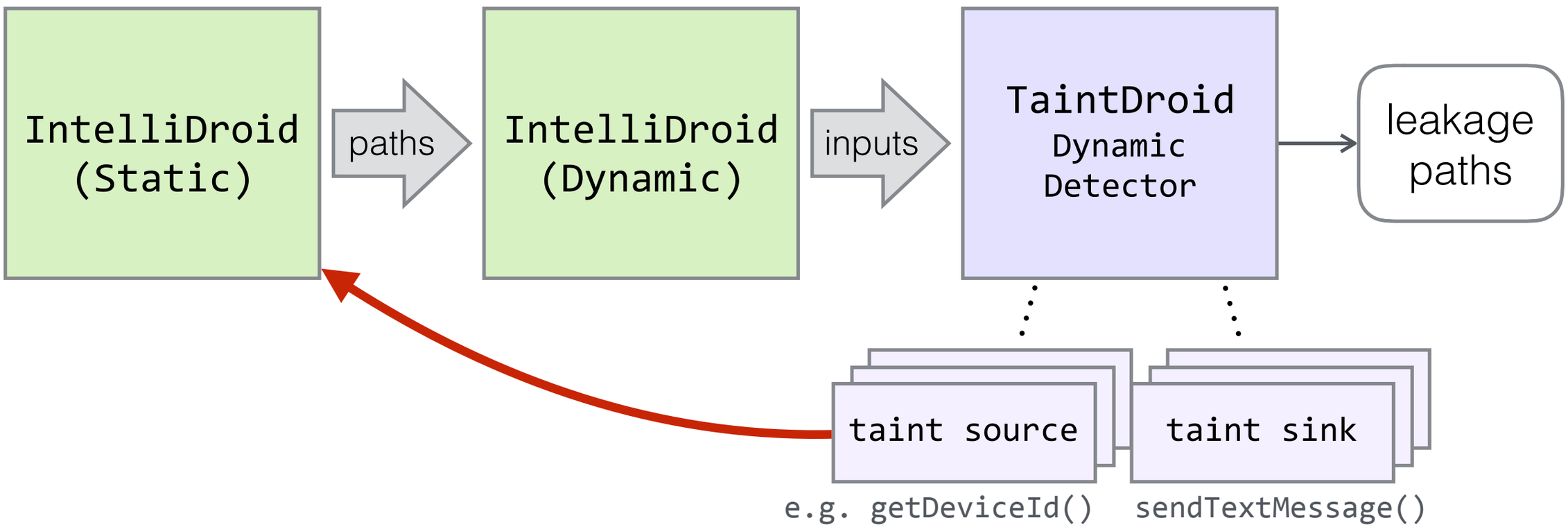
[2] Leonardo De Moura and Nikolaj Bjørner. Z3: An efficient SMT solver. In Tools and Algorithms for the Construction and Analysis of Systems, pages 337–340. Springer, 2008.

Evaluation

- Can IntelliDroid be integrated with existing dynamic malware detectors?
- Can it execute targeted behaviours at run-time?
- Is the analysis time reasonable?

Integration with TaintDroid

- Attached to TaintDroid (dynamic taint tracking tool)
- Input generator to execute taint sources and sinks



IntelliDroid-Driven TaintDroid

- Tested on 26 privacy leaks in 17 malicious apps [1,2]
- IntelliDroid: Triggered and detected all leaks
  - Monkey: Missed 21 leaks
- Executed < 5% of application code

[1] Yajin Zhou and Xuxian Jiang. Dissecting Android malware: Characterization and evolution. In Proceedings of the 2012 IEEE Symposium on Security and Privacy, pages 95–109. IEEE, 2012.

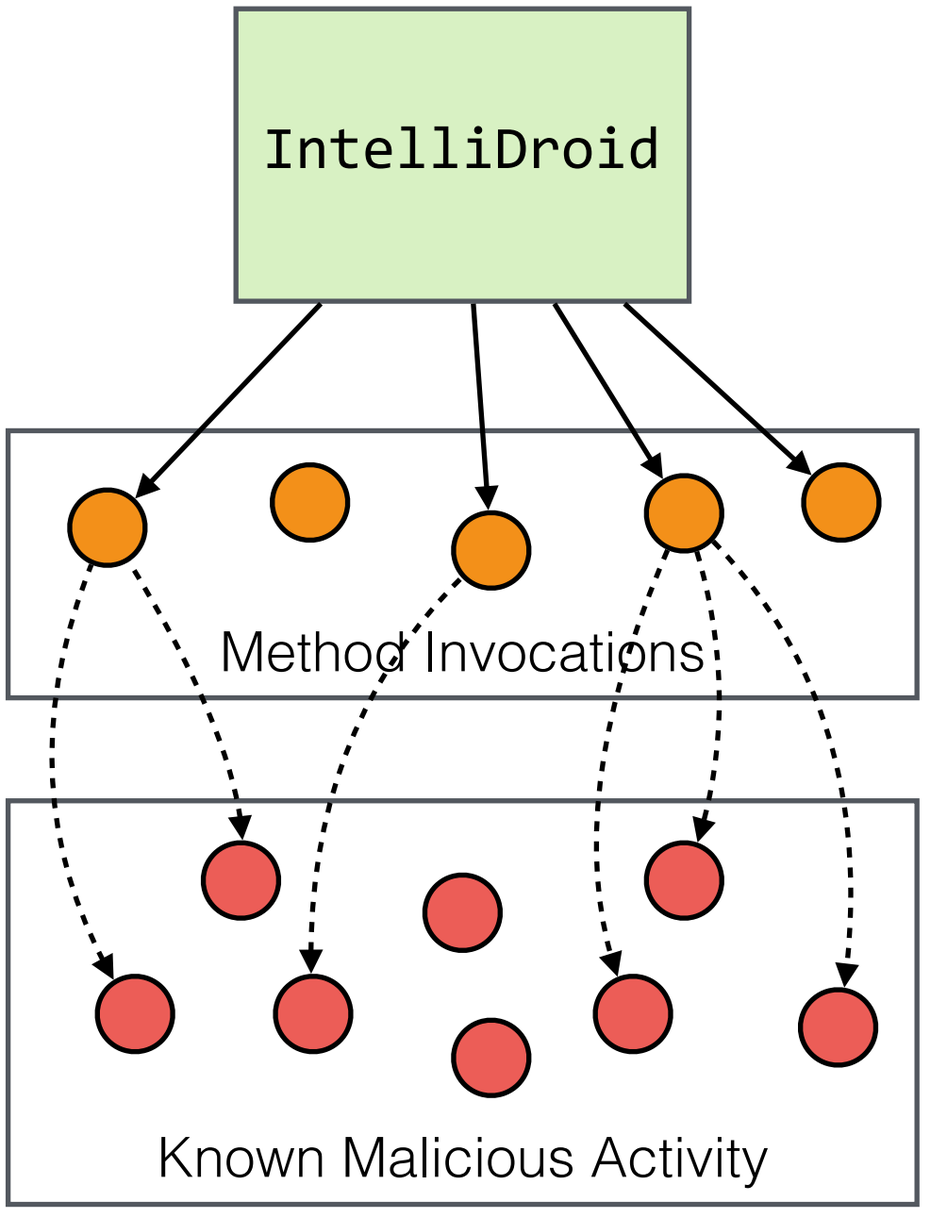
[2] M. Parkour, “Contagio mobile,” 2015, http://contagiominidump. blogspot.ca/, Last Accessed Aug, 2015.

Targeted Input Injection

- Target malicious behaviours in Android Malware Genome and Contagio

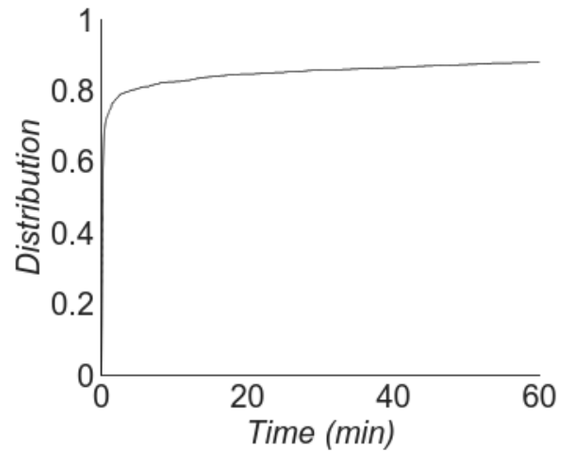
- Triggered 70 out of 75 behaviours

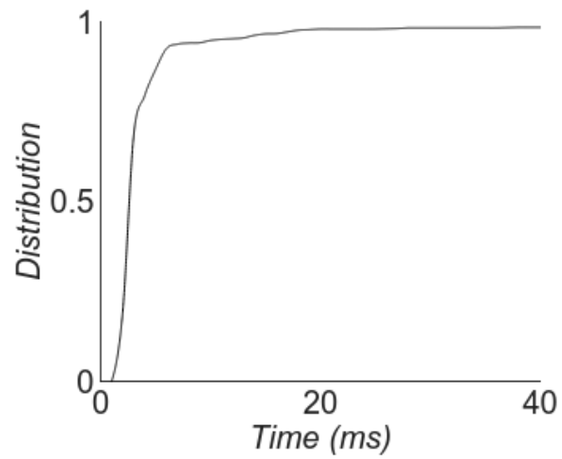
- Missed behaviors:
  - Encoding
  - File dependencies (currently not supported)



Performance

- Scales for large-scale analysis of applications
- Static analysis:
  - 138.4s per application
- Dynamic constraint solving:
  - 4.22ms per targeted call path





[1] David Barrera, Jeremy Clark, Daniel McCarney, and Paul C. van Oorschot. Understanding and improving app installation security mechanisms through empirical analysis of android. In Proceed- ings of the Second ACM Workshop on Security and Privacy in Smartphones and Mobile Devices, SPSM '12, pages 81–92, New York, NY, USA, 2012. ACM.

Conclusion

- Targeted input generation for effective dynamic malware detection
- IntelliDroid
  - Static constraint extraction with run-time data
  - Event chains and framework injection
- Integrated with existing dynamic tools (TaintDroid)
- Improve effectiveness, reduce amount of code to be executed (< 5%)