Software Defined Networking

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In this course, you will learn about software defined networking and how it is changing the way communications networks are managed, maintained, and secured.

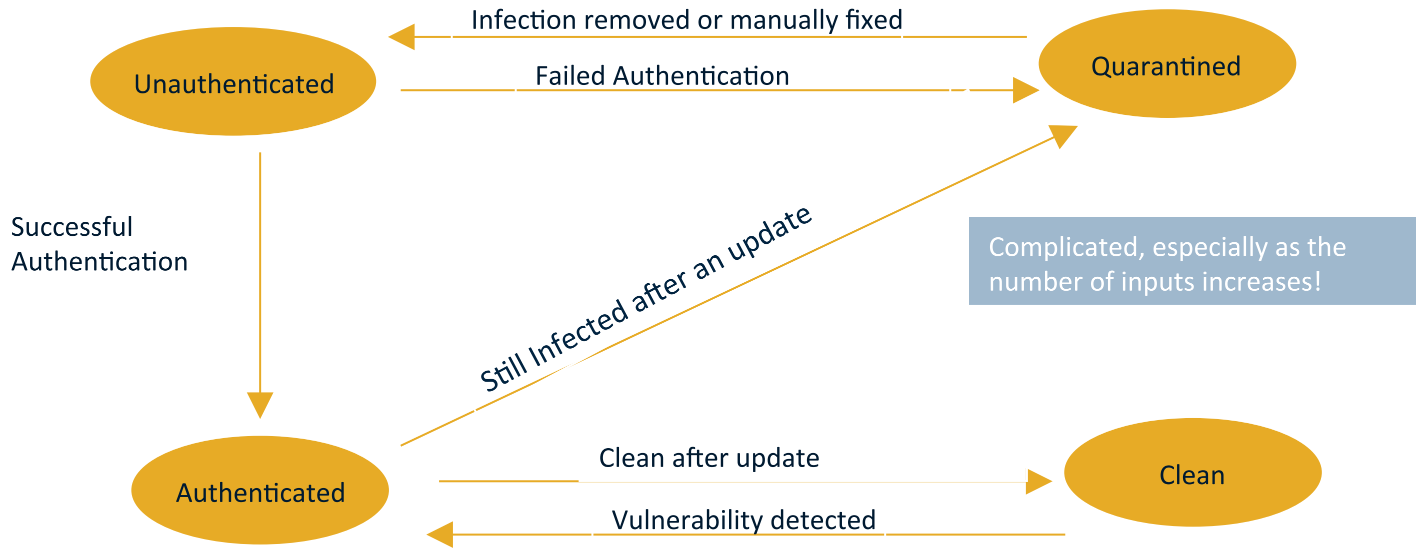
This Module: Verification

- **Motivation:** How do you know the network is doing the right thing?
- Verification techniques
  - Configuration Verification: rcc (pre-SDN)
  - **Control Plane Verification: Kinetic**
  - Data Plane Verification
    - Header Space Analysis
    - Veriflow

Configuration Changes are Common

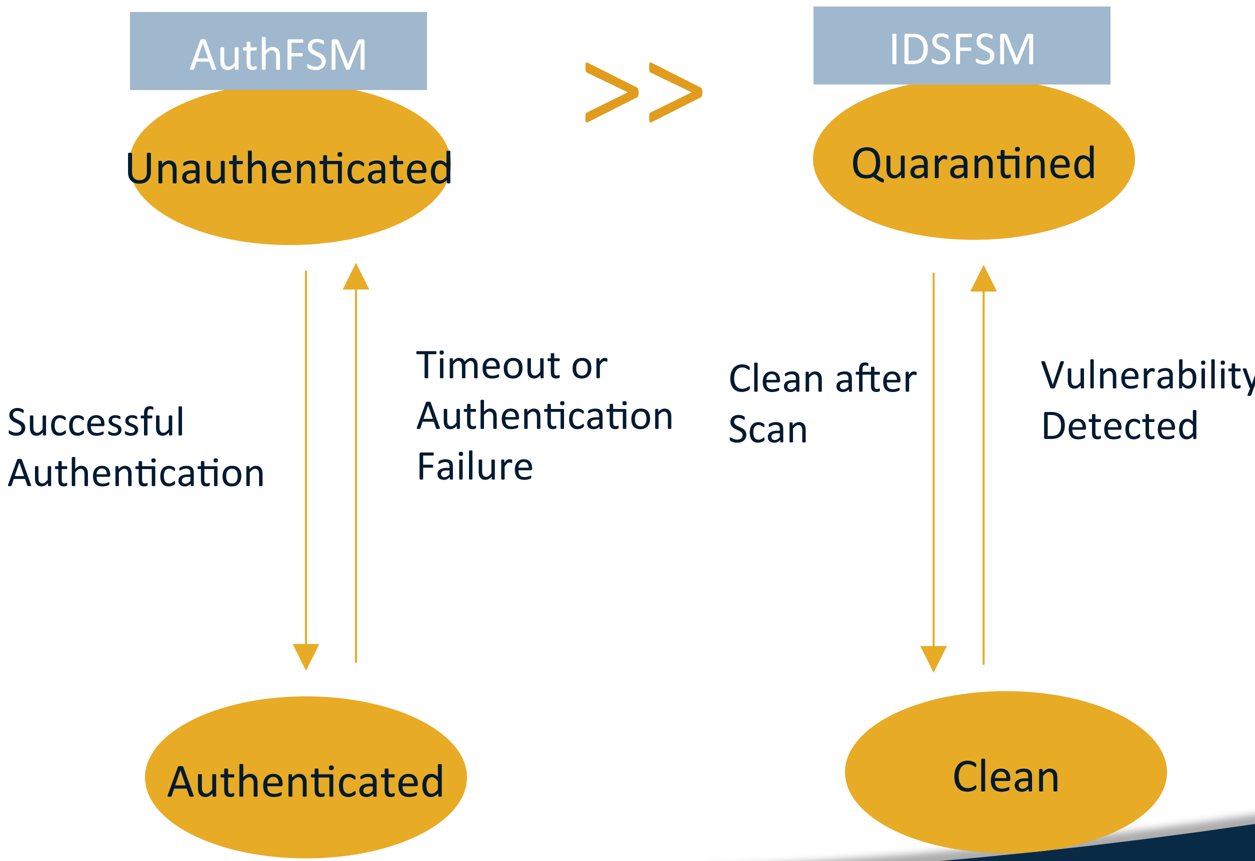
- Anywhere from 1,000-18,000 configuration changes per month
- Some of these changes can be automated, but there is no way to reason about them
- Need: Domain-specific support for expressing controller dynamics

Kinetic: Verifiable Event-Based Network Control



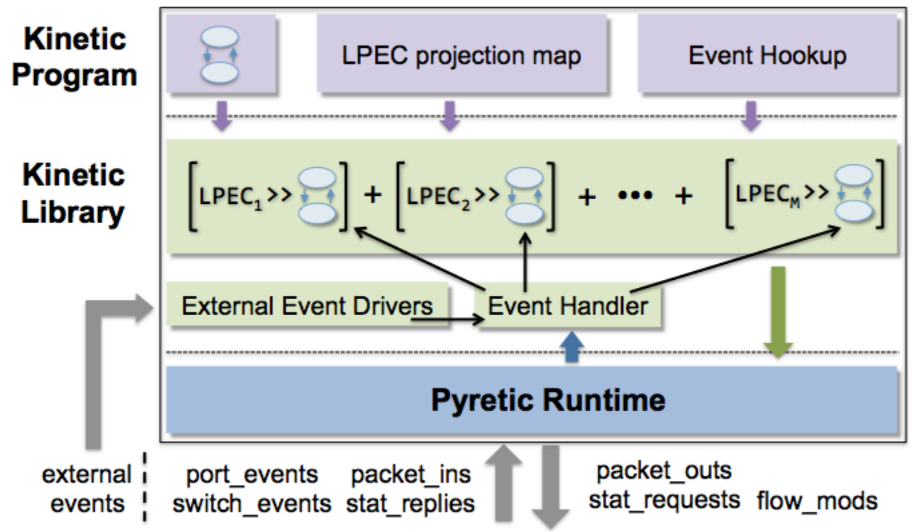
- Network policies represented as FSMs
- FSMs are verifiable!

Simpler: Sequential Composition



Simpler: Use Pyretic to sequentially compose FSMs!

Kinetic System Architecture



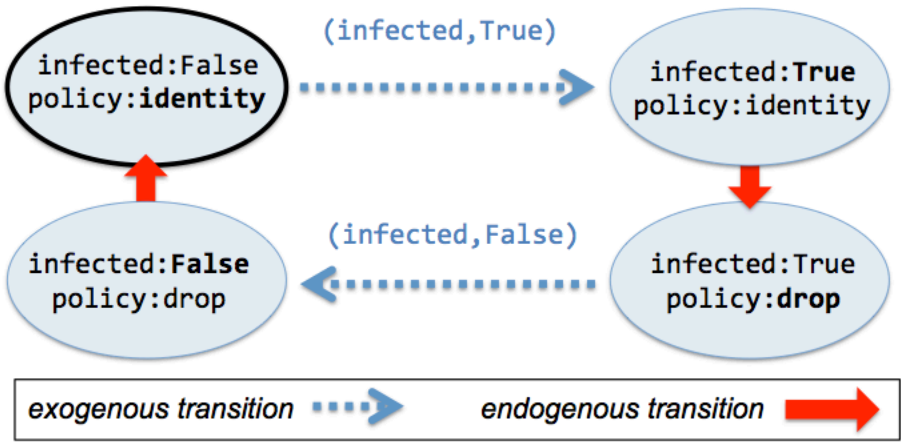
- LPEC projection map divides located packets into equivalence classes
- Event hookup for external events

Kinetic Language Architecture

Kinetic	K ::=	P | FSMPolicy(L,M) | K + K | K >> K
	L ::=	*f* : *packet* -> F
	M ::=	FSMDef([*var_name*=V])
	V ::=	VarDef(*type*,*init_val*,T)
	T ::=	[case(S,D)]
	S ::=	D==D | S & S | (S | S) | ! S
	D ::=	C(*value*) | V(*var_name*) | event
Pyretic	P ::=	Dynamic() | N | P + P | P >> P
Static Pyretic	N ::=	B | F | modify(h=v) | N + N | N >> N
	F ::=	A | F & F | (F | F) | ~F
	A ::=	identity | drop | match(h=v) |
	B ::=	FwdBucket() | CountBucket()

- Extensions to Pyretic
- Special dynamic policy class FSMPolicy
- FSM descriptions and basic values

Example: Intrusion Detection System




```
@transition
def infected(self):
  self.case(occured(self.event),self.event)

@transition
def policy(self):
 self.case(is_true(V('infected')),C(drop))
 self.default(C(identity))

self.fsm_def = FSMDef(
 infected=FSMVar(type=BoolType(),
                 init=False,
                 trans=infected),
 policy=FSMVar(type=PolType({drop,identity}),
               init=identity,
               trans=policy))
```

- Two types of transitions
  - **Exogenous:** Triggered by external event
  - **Endogenous:** Triggered by change in internal variable

LPEC: Define the Granularity of the FSM

Step (1)

```
match(srcip=IPAddr('10.0.0.1'))
```

Step (2)

```
def ids_lpec_pm(pkt):
    return match(srcip=IPAddr('10.0.0.1'))
```

Step (3)

```
def ids_lpec_pm(pkt):
    return match(srcip=pkt['srcip'])
```

- Specify Located Packet Equivalence Class (“LPEC”)
- Define projection MAP
- Parameterize using input packet

Conversion to NuSMV

```
MODULE main
  VAR
    policy   : {identity ,drop};
    infected : boolean;
  ASSIGN
    init(policy)   := identity;
    init(infected) := FALSE;
  next(policy) :=
    case
      infected : drop;
      TRUE     : identity;
    esac;
  next(infected) :=
    case
      TRUE    : {FALSE,TRUE};
      TRUE    : infected;
  esac;
```

- FSMs translate directly to NuSMV model checker
- Can check properties in CTL

CTL Examples for Kinetic IDS

NuSMV	Description
`AG infected → (policy=drop)`	If infection event arrives, the system should drop the packet.
`AG !infected → (policy=identity)`	If infection is cleared, the system should allow the packet.
`AG EF policy=identity`	From any state, it is possible to go to allowed state again.
`A [ policy=identity U infected ]`	For all paths, policy allows packet until an infection occurs.

- Rules expressed using CTL
- Branching-time logic, time as a tree structure

Summary

- Event-based control is a common idiom
- Need to verify dynamic properties of network control, not only data-plane properties
- Kinetic: Verifiable dynamic network control
  - Policies expressed as FSMs
  - FSMs map naturally to model checking
  - Properties can be checked in CTL