Model Based Testing

Connecting Specifications and Testing

A working definition

- Model-based testing is

“The *automatic generation of efficient test procedures/vectors using models* of system requirements and specified functionality.”

www.goldpractices.com/practices/mbt/index.php

- There are also *benefits* of model creation and analysis *beyond that of automated test generation*, e.g. validation of requirements
- Mostly *for integration and acceptance testing*

Why a formal model?

- *Informal specification documents enable* engineers to get *vague understanding of system functionality*
- Reliance on such implicit, mental, informal models renders testing process that is
- *Unstructured*
- *Hardly reproducible*
- *Unmotivated in its details*
- Informal models *cannot support automated test generation and validation*

Cost-benefit analysis

- *Model creation costs time/money*, but:
- *Systems* get *more complex*, release *schedules shorter*
- *Automated* model-based *test generation* now possible
- *Testing* is *50-70% of total cost* of product release, clear need to cut that cost factor
- *Models* can be reused, *can correct requirements*, can inform design activities

→ *Model-based testing often cost-effective but requires certain skills within organization*

Possible workflow

1. *Build the model*; e.g. finite-state machine abstraction of system's event structure
2. *Generate expected inputs*; e.g. trace of events for finite-state machine
3. *Generate expected output*; e.g. target state
4. *Compare* actual *output* with expected one, e.g. was target state reached?
5. *Decide on further actions*; e.g. modify model, generate more tests, estimate reliability

Model building during development

- Requirements engineer, designer, tester, or developer *forms mental representation of system's functionality*
- *Describes/expands* mental *model in* easily understandable *formalism*
- Uses formalism and choice of model that *facilitate frequent, automated, and effortless test generation*

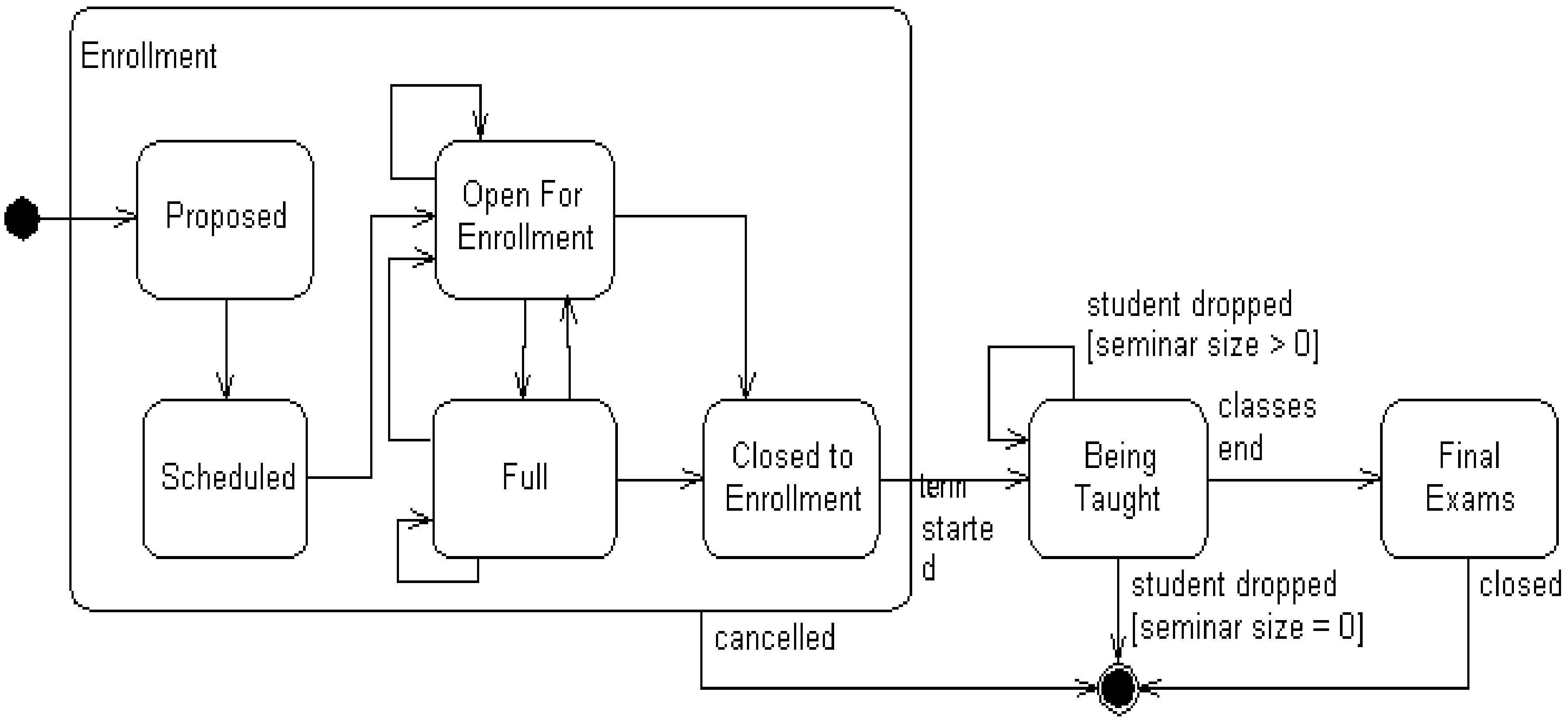
Model creation: other needs

- E.g. *maintenance*: often requires *automated extraction of information from system artifacts*, e.g. from documentation, source code, data files etc.
- Many useful kinds of information: *call graphs*, file dependences, *frequent usage patterns*, event interactions, etc.
- *Example application*: extract event interactions from black-box legacy system, use that model to determine causal structure of events

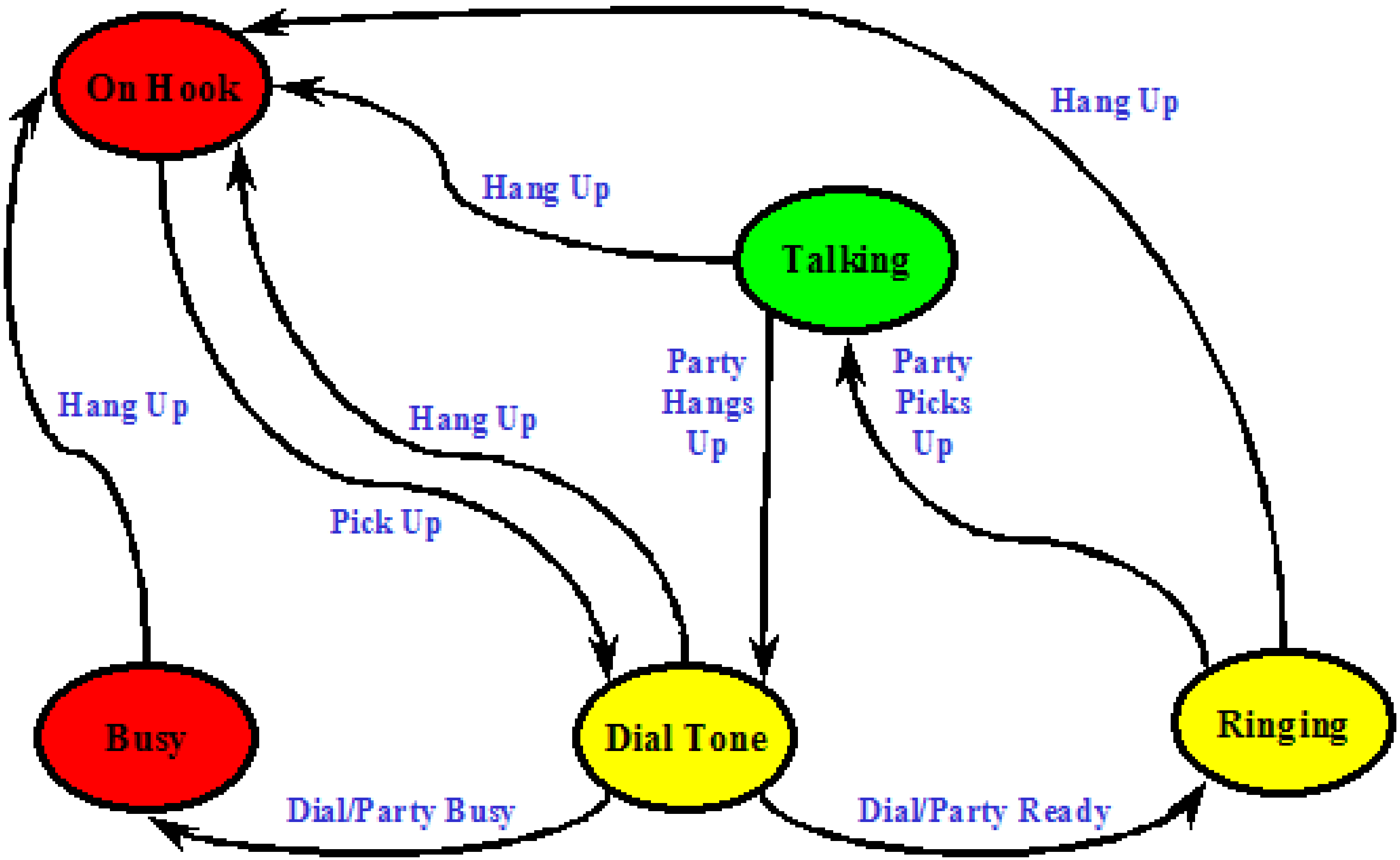
Kinds of behavioral models, all have tool support

- *Decision tables*: tables showing sets of conditions and actions that result from conditions being true
- *Finite-state machines (FSM)*: finite number of states and transitions (possibly labeled with actions) between them
- *Markov chains*: like finite-state machines but *transitions guided by probability distribution*
- *State charts*: UML diagram, shows states that system can assume, shows circumstances that cause state change

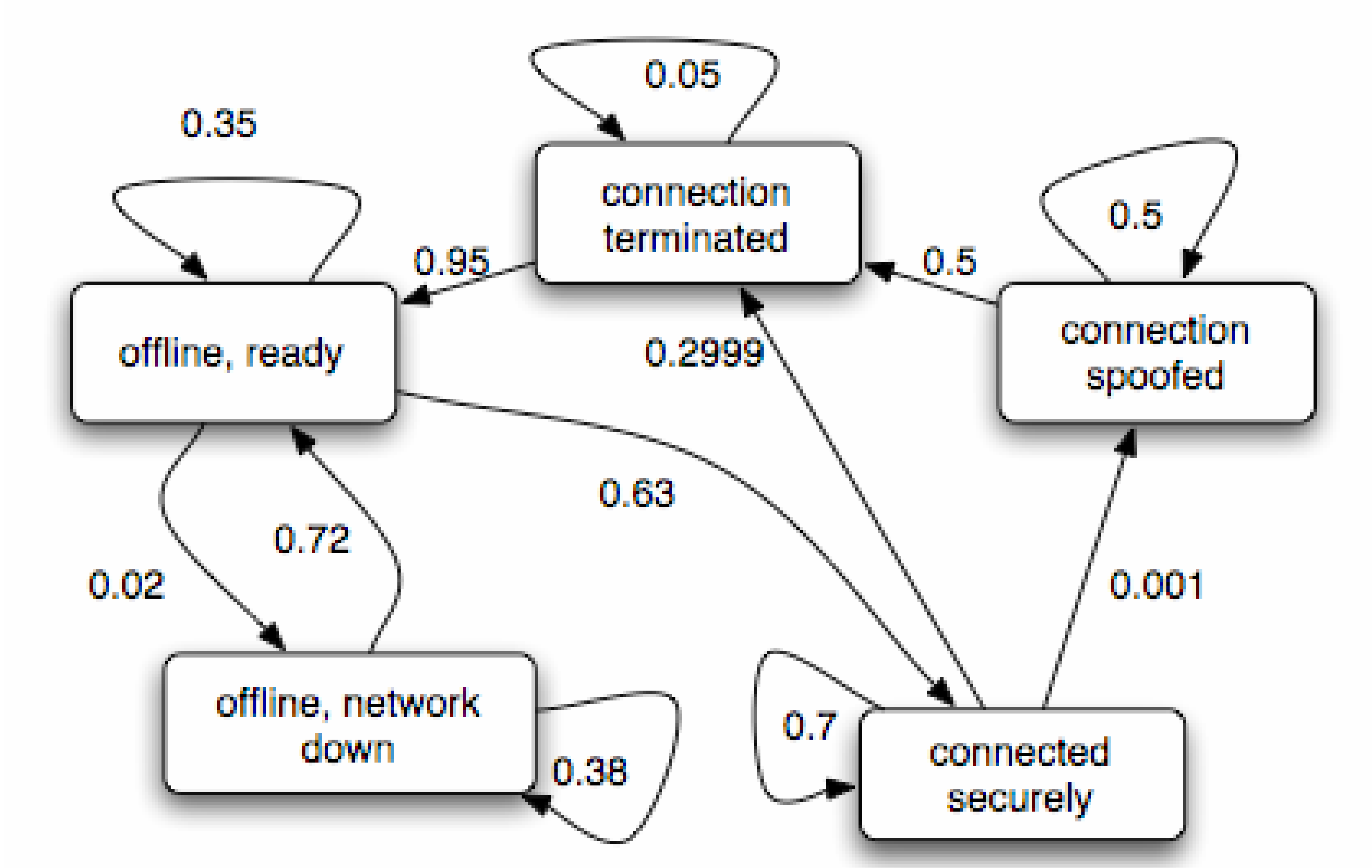
Example of a state chart



Example FSM model



Example of Markov chain



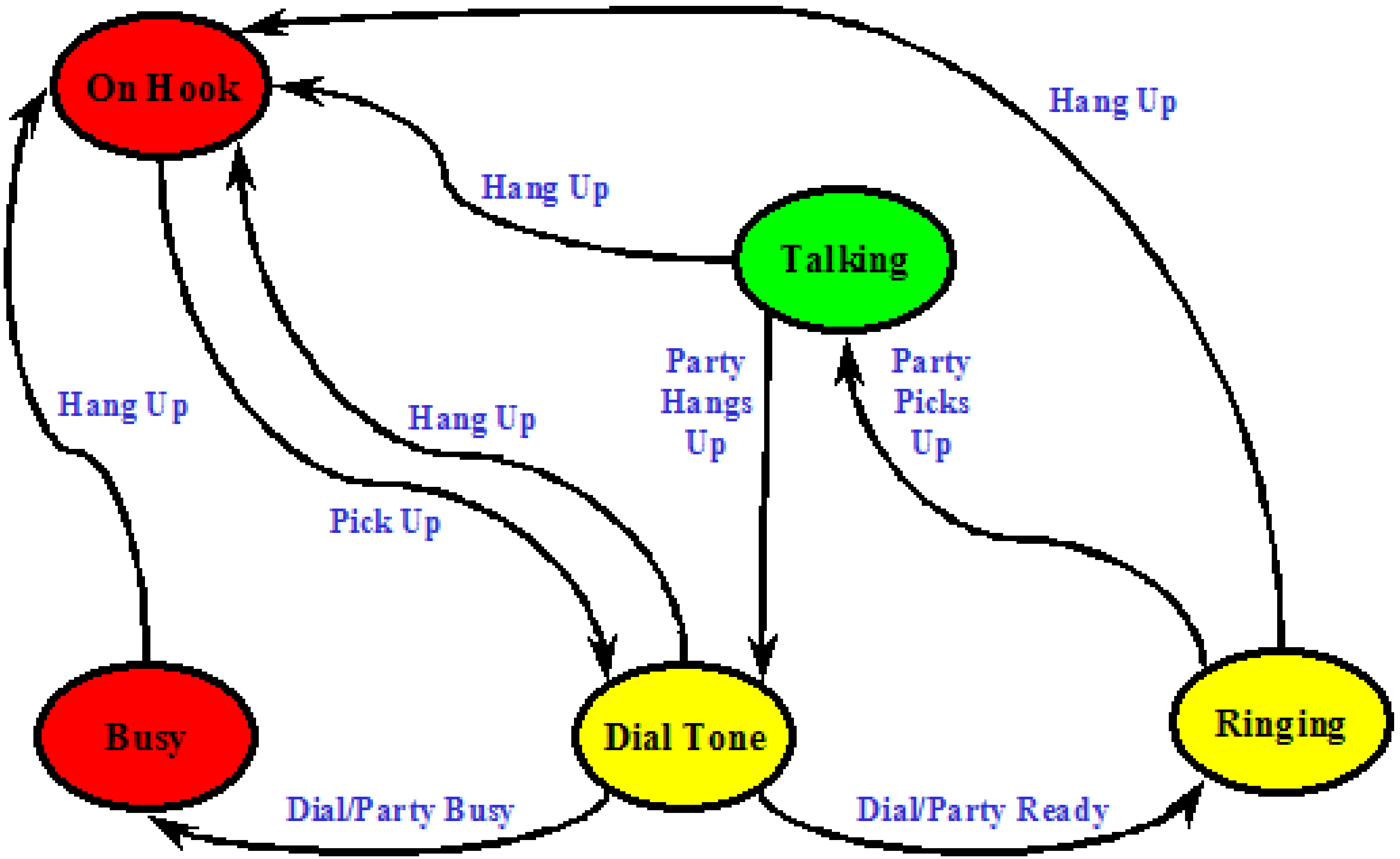
Choice of modeling method

- E.g. *use finite-state machines to model state-rich system* such as telephony
- E.g. *use state charts for system with few states,* or hierarchical structure, transitions caused by user input and external conditions
- E.g. *use Markov chains when statistical analysis*, failure data, or reliability assessments are *desired*

Heuristics for building a model

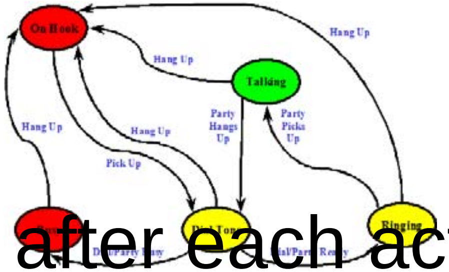
1. List all inputs
2. For each input: *list situations in which input can be applied*; ditto for situations in which it *cannot be applied*
3. For each input: *list situations in which input causes different behaviors* or outputs, depending on application context of input

Recall FSM model



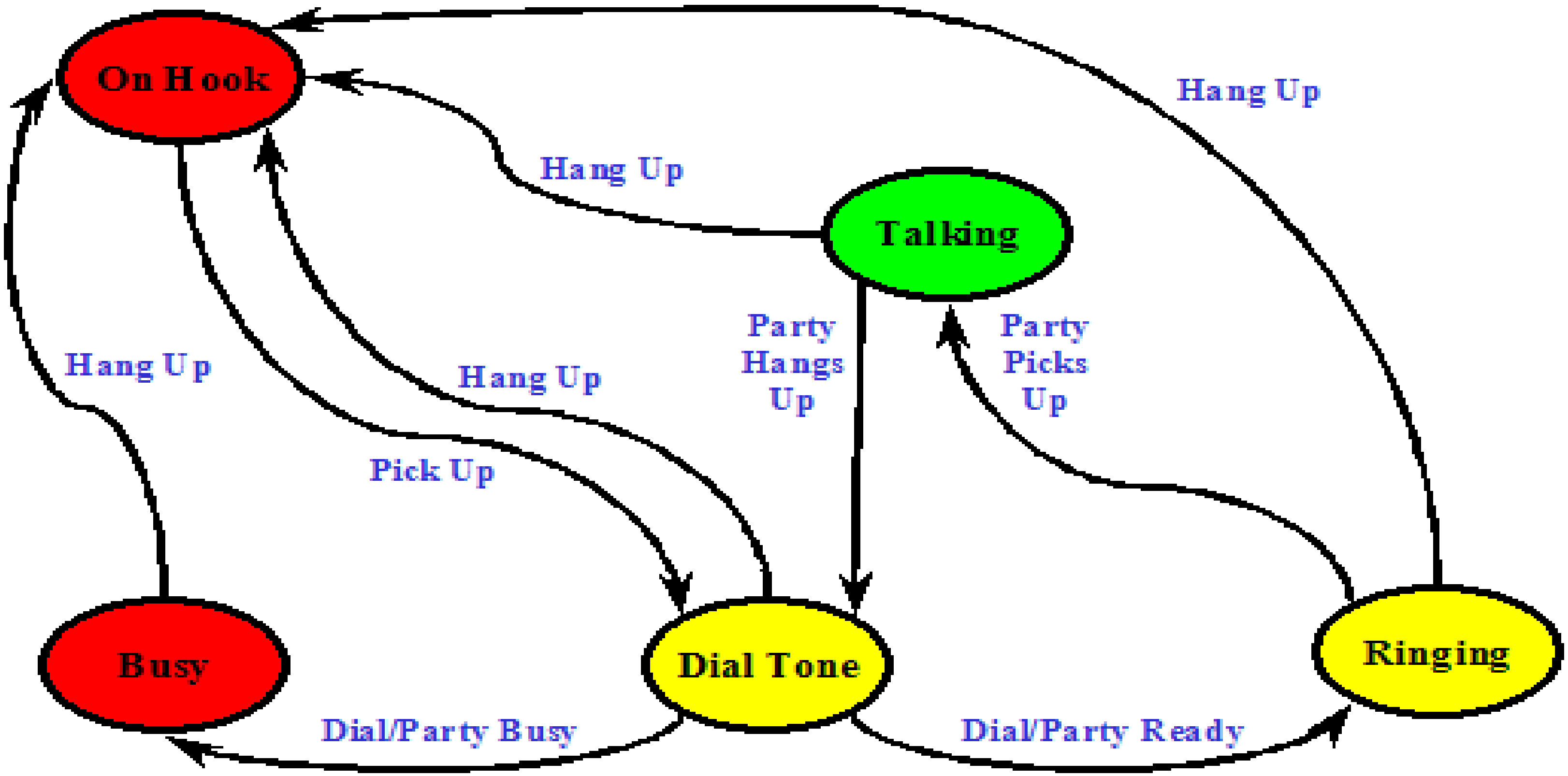
Details of example FSM model

- FSM is *model of simple phone system*
- Model is of *phone that can call out*
- *Nodes are states of phone*, e.g. OnHook
- *Edges are actions user can take*, i.e. system input, e.g. HangUp
- Test cases specify



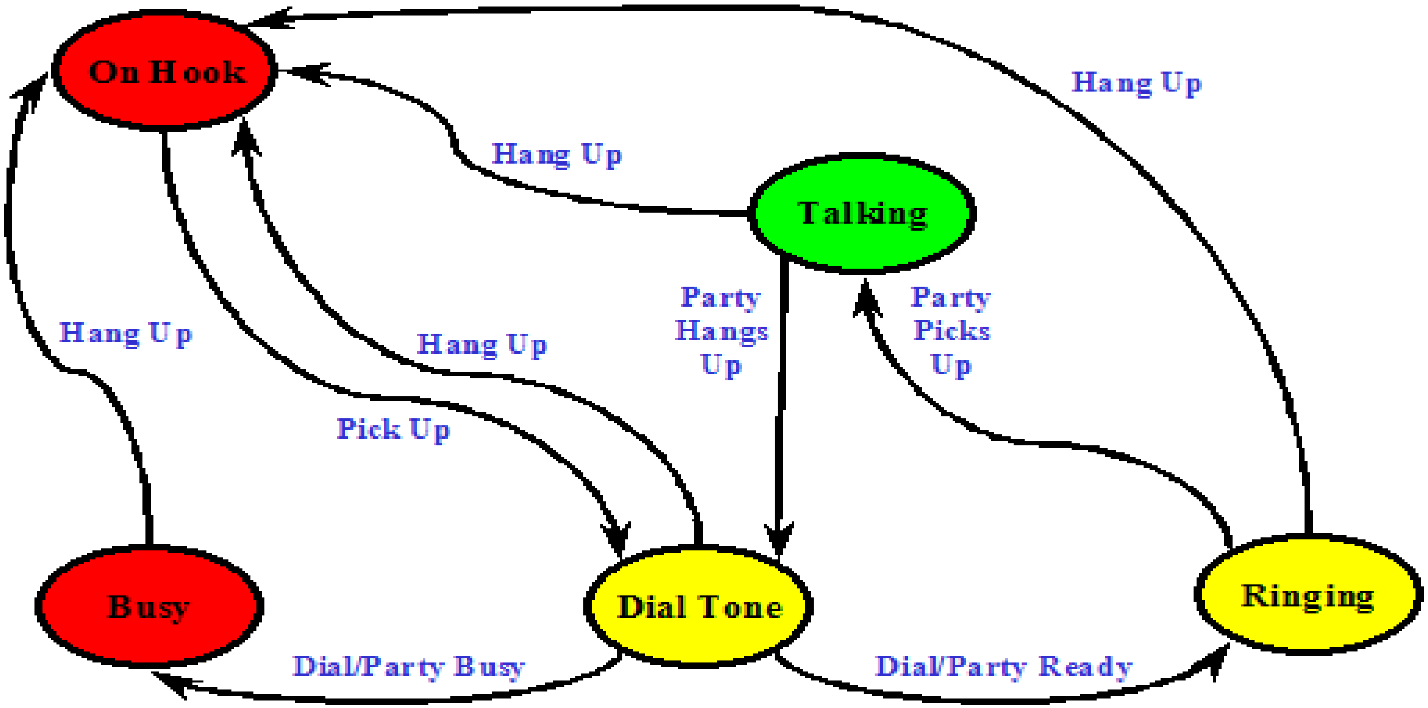
- *sequence of inputs*
- *states system should reach* after each action
- and *value of outputs* of system

Generating test cases



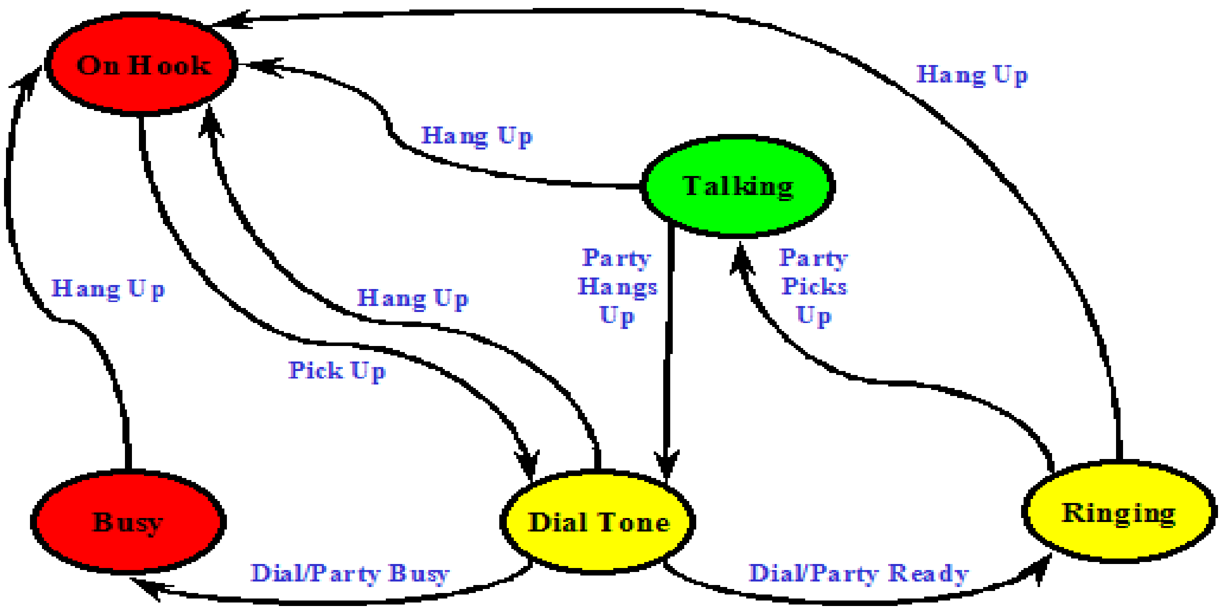
OnHook *<PickUP>* DialTone *<Dial/PartyBusy>* Busy *<HangUp>* OnHook *<PickUp>* DialTone *<Dial/PartyReady>* Ringing … *// Exercise: extend sequence to cover all transitions*

Action coverage



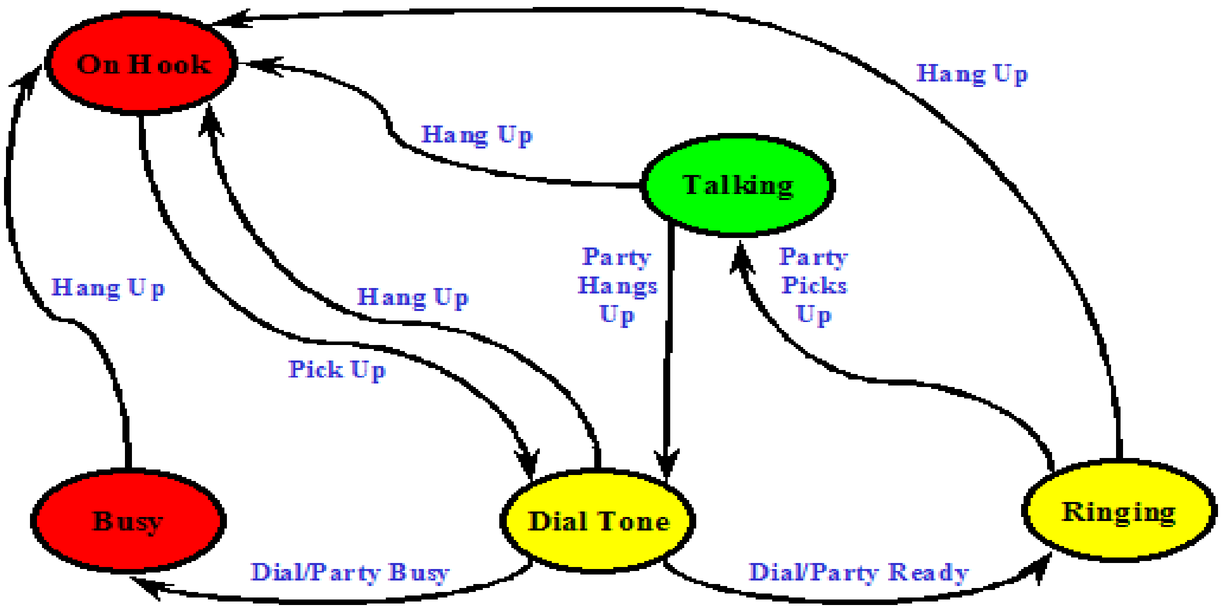
OnHook *<PickUP>* DialTone … sequence (from previous slide) has 15 inputs, achieves *action coverage*: every action possible at each state "executed" at least once; *easiest test coverage criterion for FSM model*

Action coverage



- Generated *action-coverage sequence not unique*, each such sequence stresses software differently but with same coverage criterion
- Said sequence consists of four test cases, i.e. sequences beginning at *OnHook*
- If system outputs only its abstract state, can *use FSM as effective test oracle*

Switch coverage



- *Switch coverage*: for each state, each pair of actions leading (into,out) of that state is in test sequence
- Switch coverage: *more rigorous than action coverage*
- Example: at DialTone we need to consider 2*3 = 6 such pairs, e.g. the pair

  <PartyHangsUp> DialTone *<Dial/PartyReady>*
- 26 (*> 15*) inputs needed for switch coverage here

From models to tests & back

- *Models deliberately abstract*: simplification enables comprehension and communication of functionality or requirements
- *Models generate test cases guided by* coverage criteria, e.g. action coverage, or other *test purposes*, e.g. “Requirement A2”
- *Generated test cases have to be concrete enough* to be executable: *test scripts/drivers*
- Executable *test results too concrete to map* directly *back to models*

→ *Automation needs to enable move from abstract to concrete and vice versa*

Test scripts

- Aka test drivers, *run automatically without human interaction*
- *Provide* general *mechanisms for supporting other test automation methods*
- E.g. capture/playback and test generation approaches
- Test scripts *developable in standard application languages* VB, C, Java, C#, Tcl, …

→ Model-based testing *needs to bridge the gap between abstract models and concrete test scripts*

Common test script pattern

- *Initialize* the *SUT*
- *Iterate*, for each test case:
- *initialize target* (optional)
- *Initialize output to value other than expected* (if possible)
- *Set inputs*
- *Run SUT*
- *Capture output* and state of results so that later on a test report can be created

Capture/playback approach

- *Captures sequences of manual operations* (e.g. in GUI) *in test script written by test engineer*
- Has shortcomings, e.g.

- needs to *recognize GUI objects when layout has changed*
- Changing system functionality *forces manual recapture of playback sequence*
- Manual recording of today's website interaction *too complex to handle*

Model-based testing: benefits

- *Comprehensive tests*: models determine logical paths, locations of program boundaries, identify reachability problems
- *Improved requirements*: testable requirement has to be complete, consistent, unambiguous; testing may expose “feature interaction” requirement defects
- *Defect discovery*: studies suggest mode-based testing results in early defect detection, sufficient for Return On Investment

Some Additional Resources

http://www.goldpractices.com/practices/mbt/index.php

http://www.geocities.com/model_based_testing/