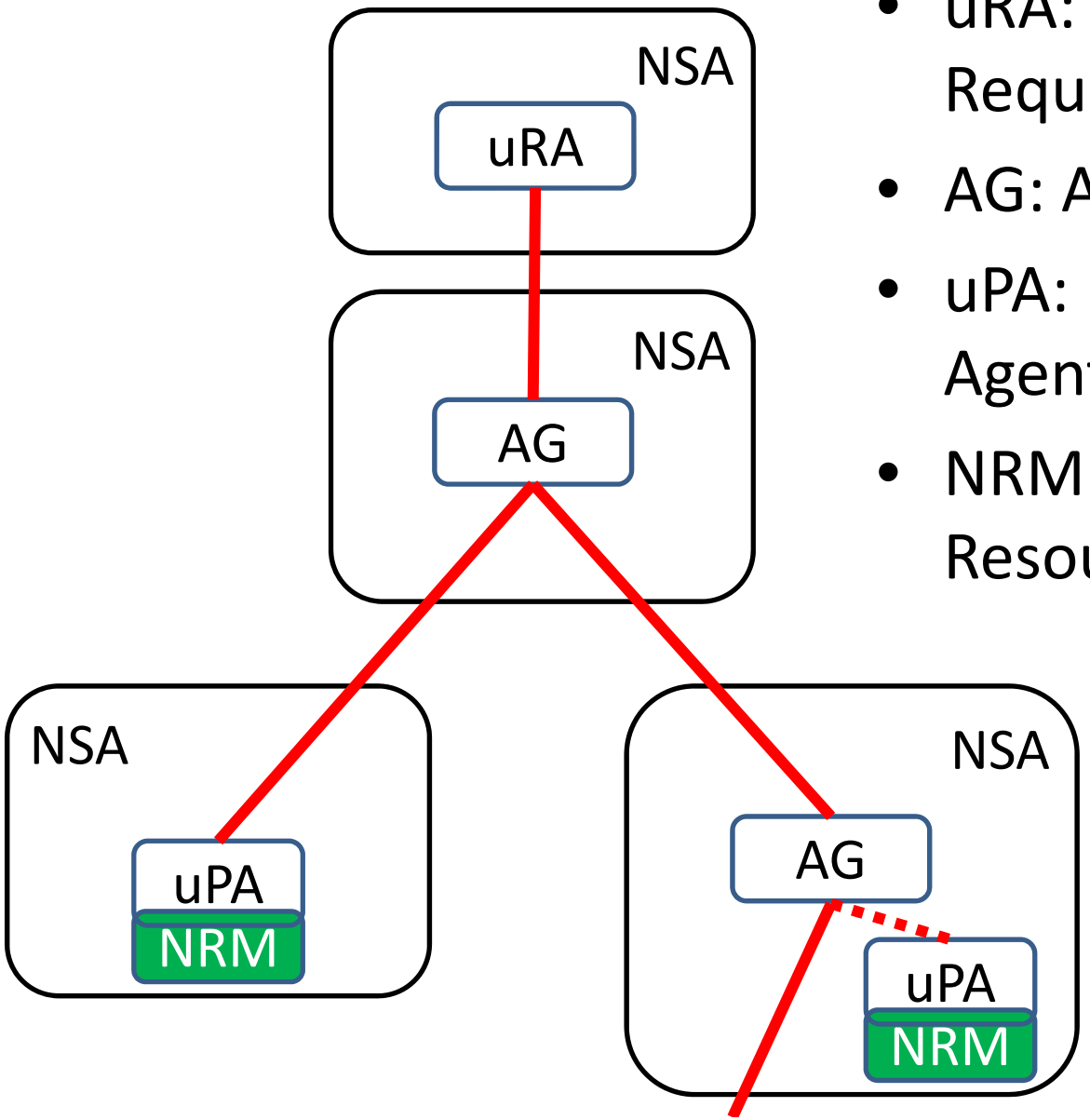
NSI CS Protocol State Machines and Message Handler

NSA: uRA, Aggregator and uPA

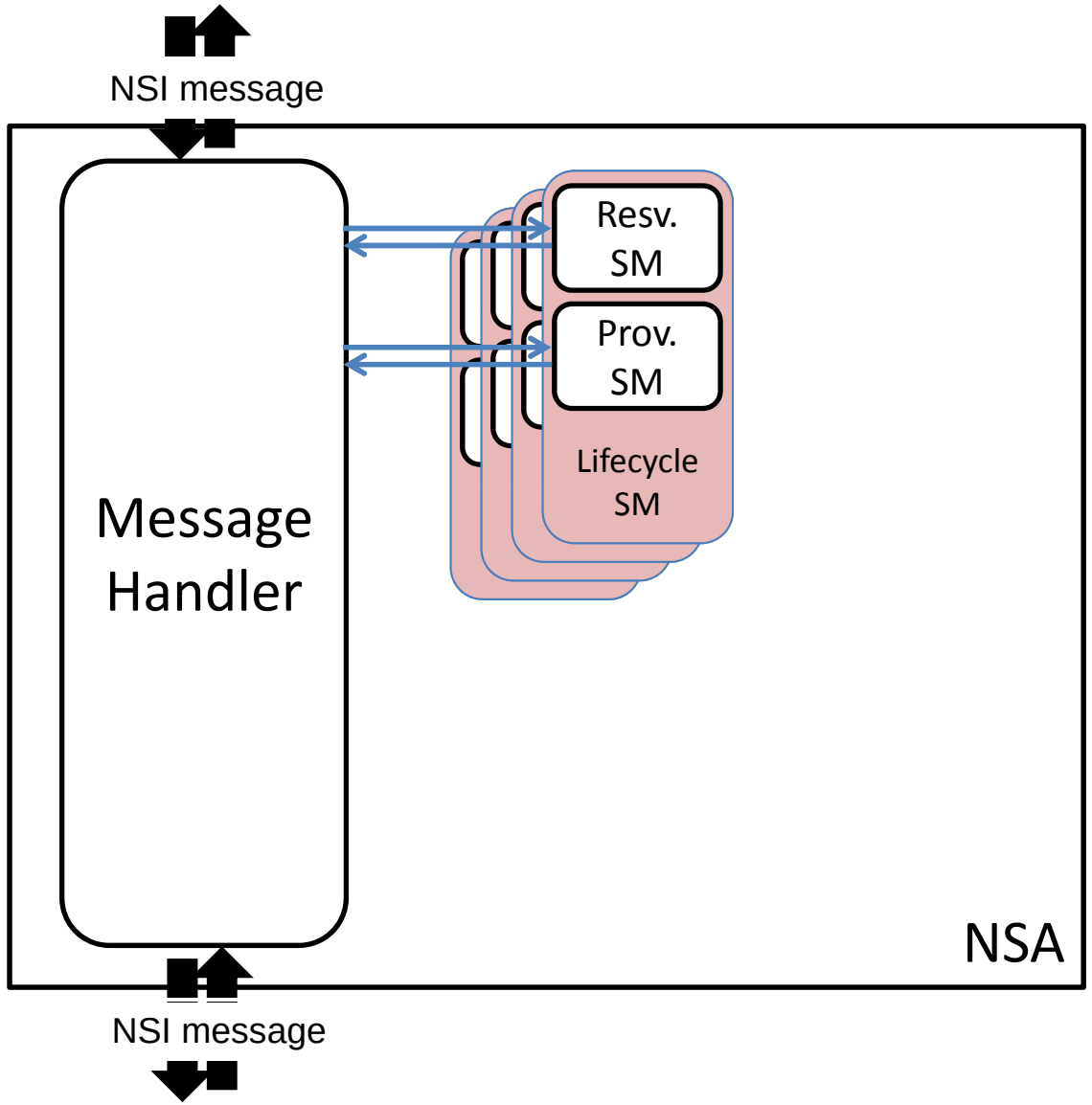


- uRA: Ultimate Requester Agent
- AG: Aggregator
- uPA: Ultimate Provider Agent
- NRM: Network Resource Manager

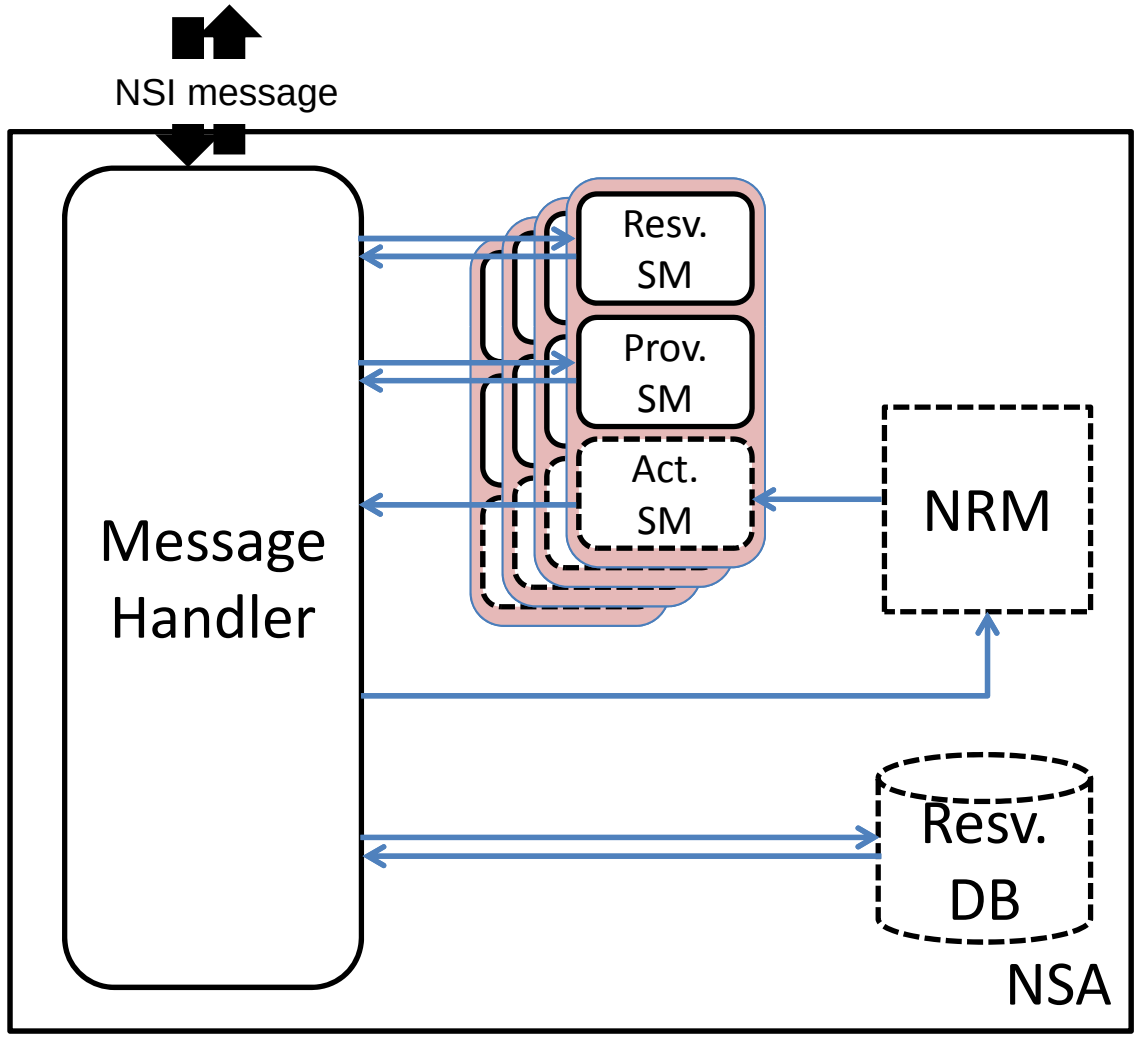
State Machines and Message Handler

- Behavior of NSI CS protocol is modeled as state machines and message handler
- State Machines:
  - RSM: Reservation State Machine
  - PSM: Provision State Machine
  - ASM: Activation State Machine
  - LSM: Lifecycle State Machine
- Aggregator:
  - can talk to upstream and downstream NSAs
  - Has RSM, PSM and LSM
- uPA
  - Can talk to upstream NSAs only
  - Has RSM, PSM, ASM and LSM

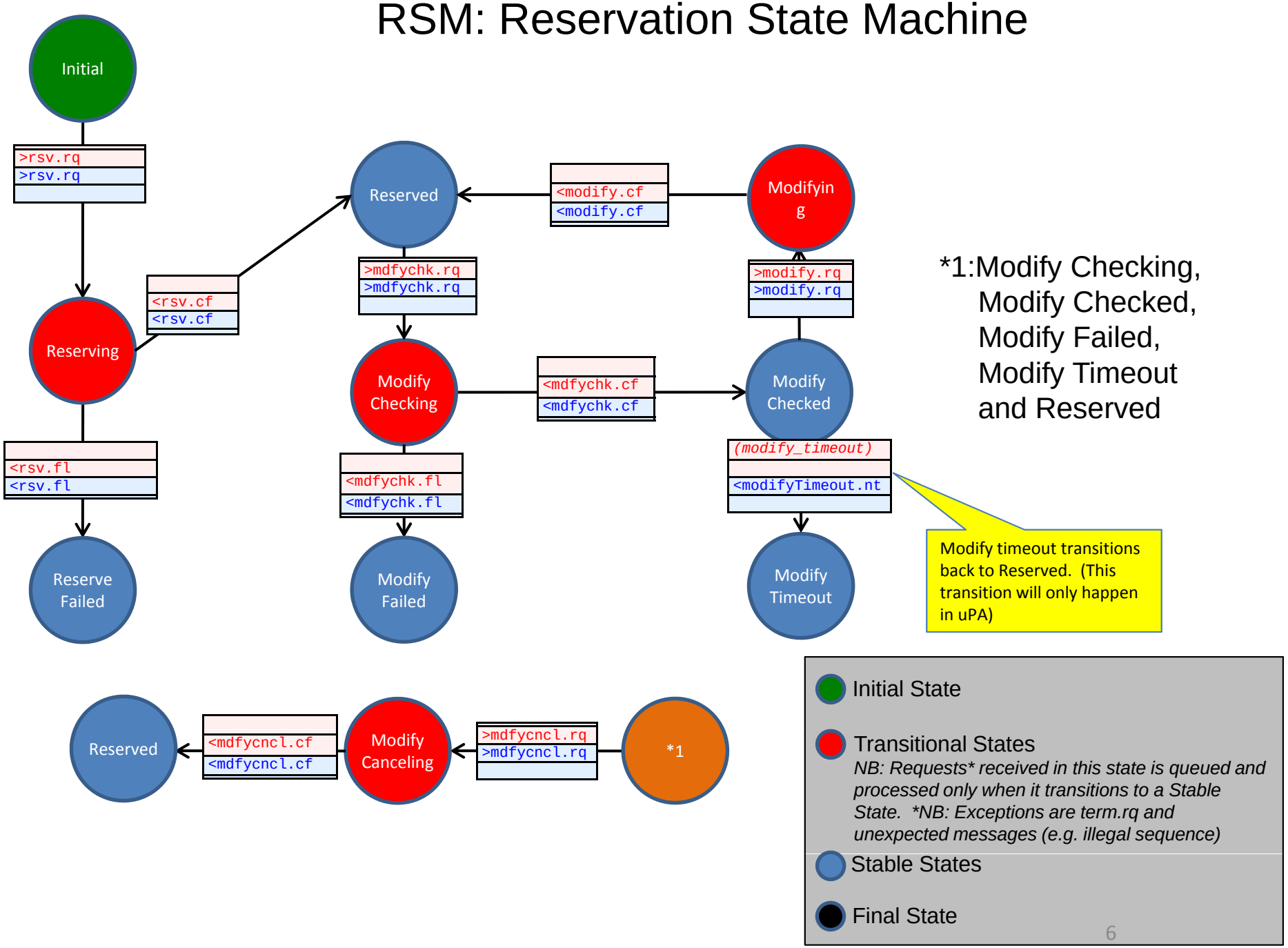
Aggregator


NSI message
Message Handler
Resv. SM
Prov. SM
Lifecycle SM
NSA
NSI message

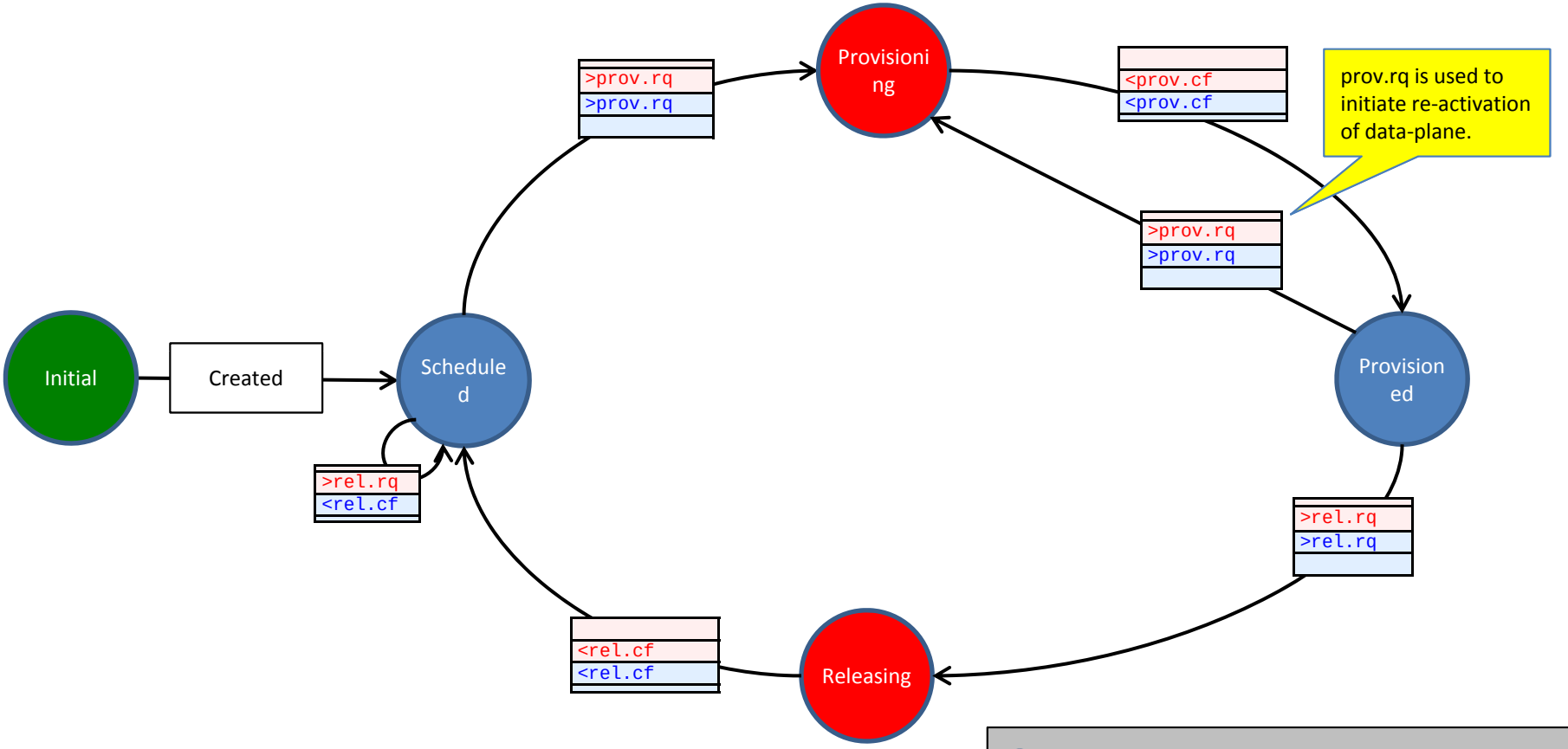
uPA


NSI message
Message Handler
Resv. SM
Prov. SM
Act. SM
NRM
Resv. DB
NSA

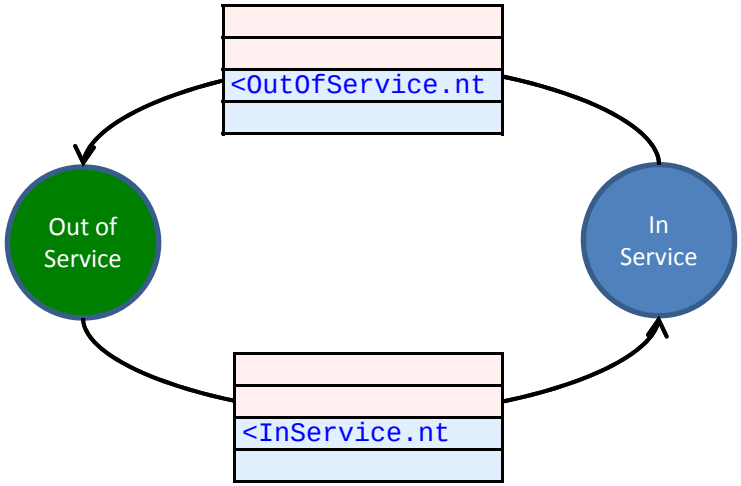
RSM: Reservation State Machine

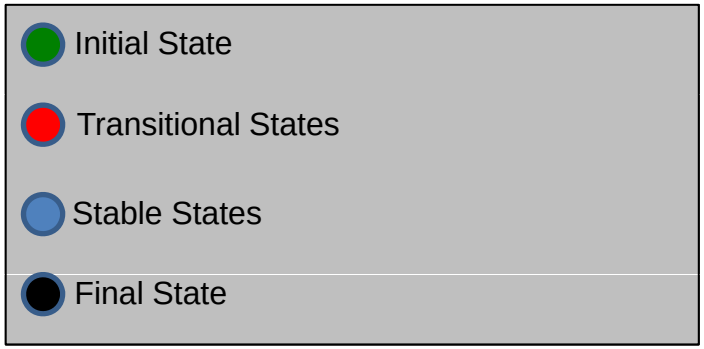


PSM : Provision State Machine

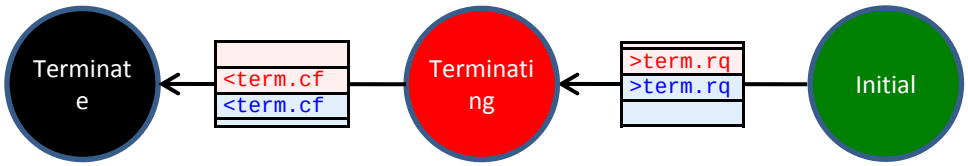


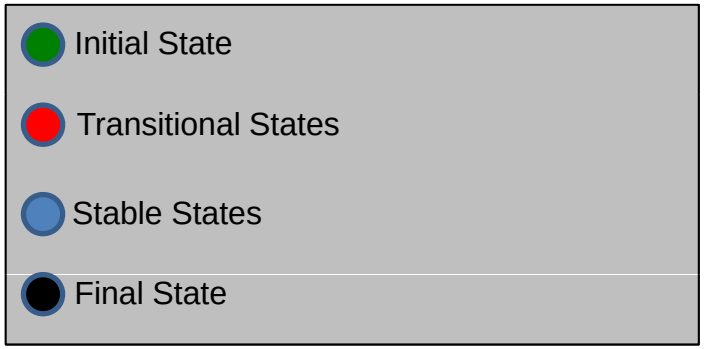
ASM : Activation State Machine



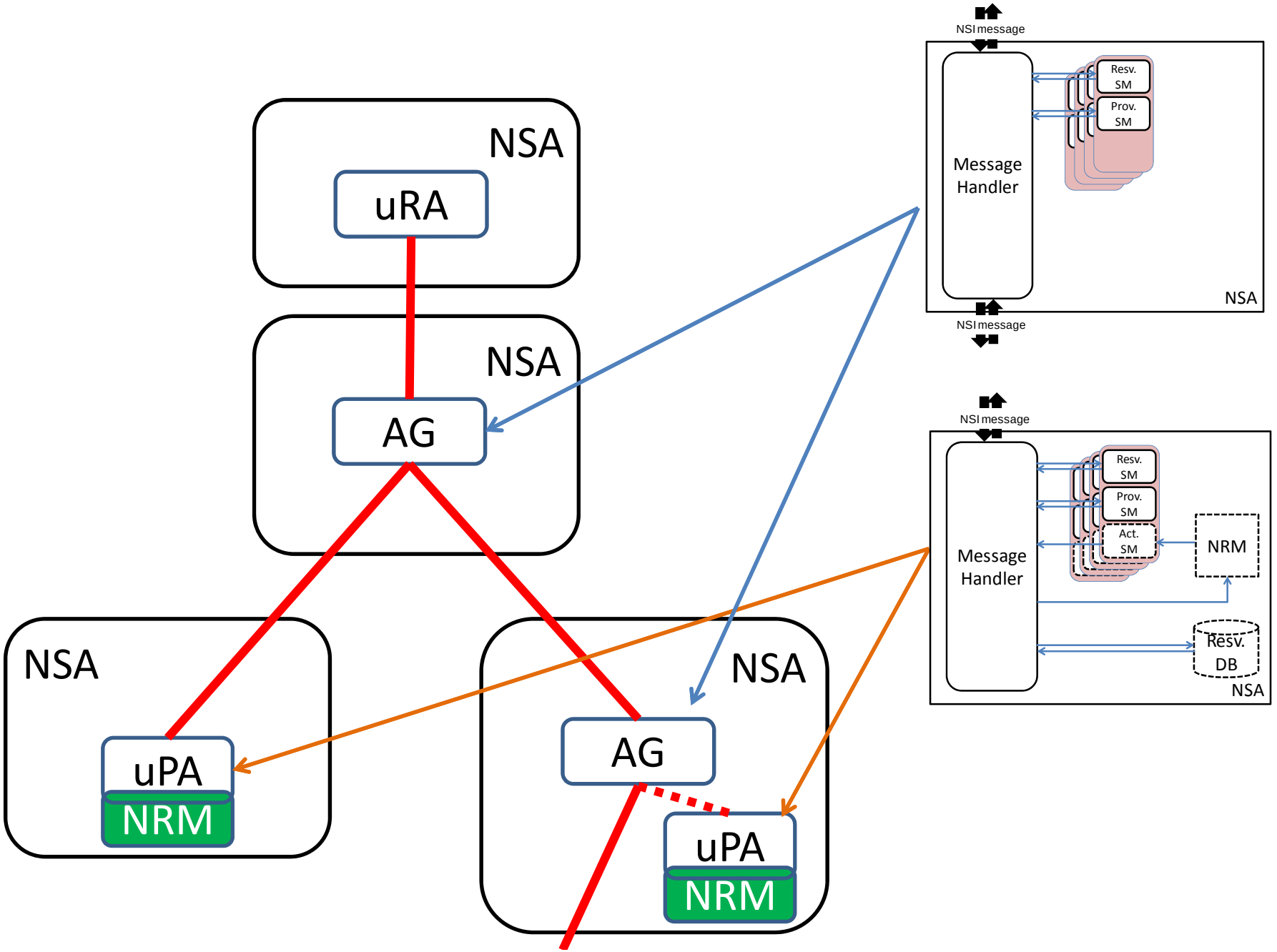


LSM : Lifecycle State Machine

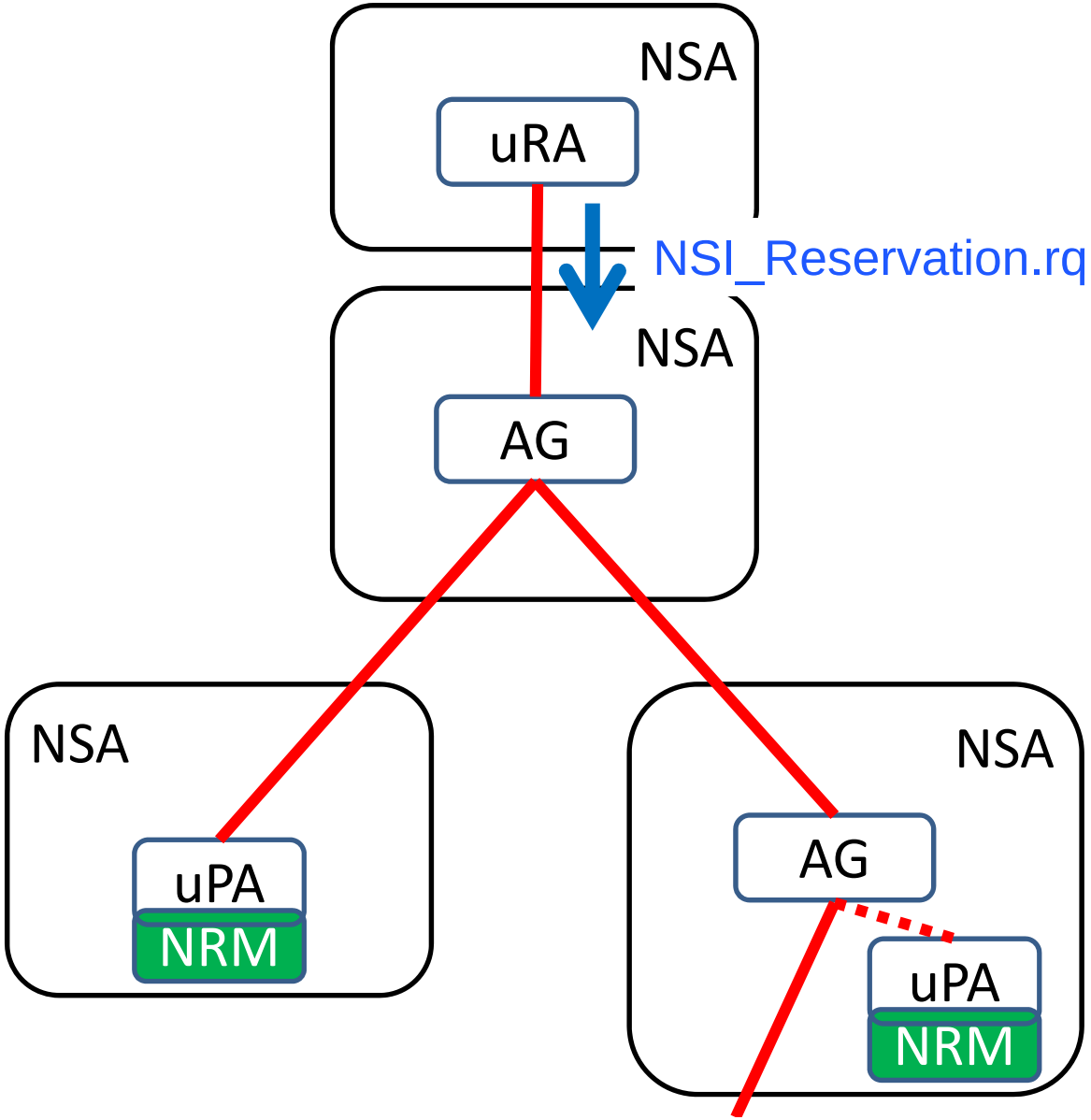




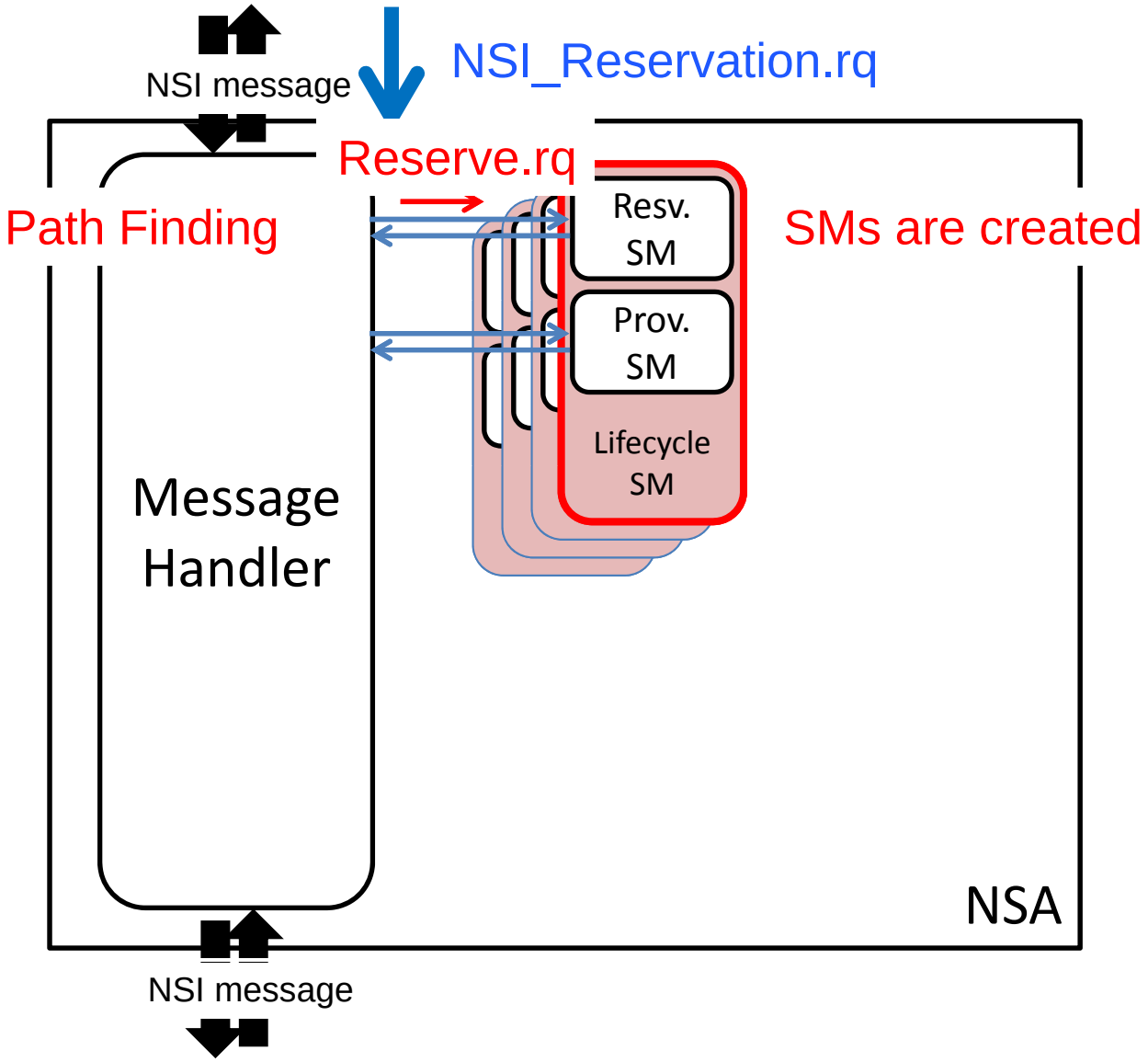
NSA: uRA, Aggregator and uPA



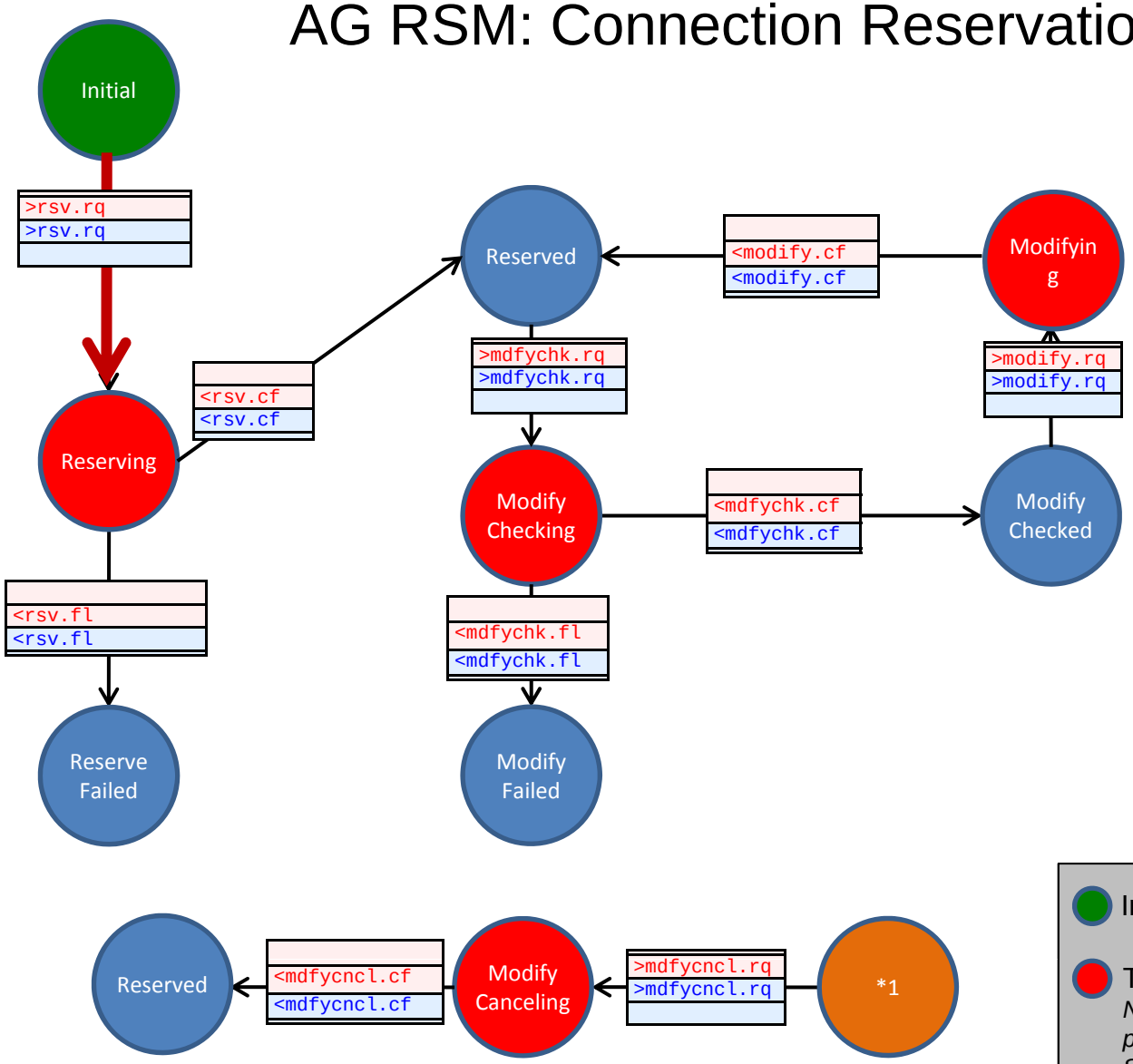
Reservation example



Aggregator NSA



AG RSM: Connection Reservation State Machine



*1:Modify Checking,
Modify Checked,
Modify Failed,
Modify Timeout
and Reserved

Initial State

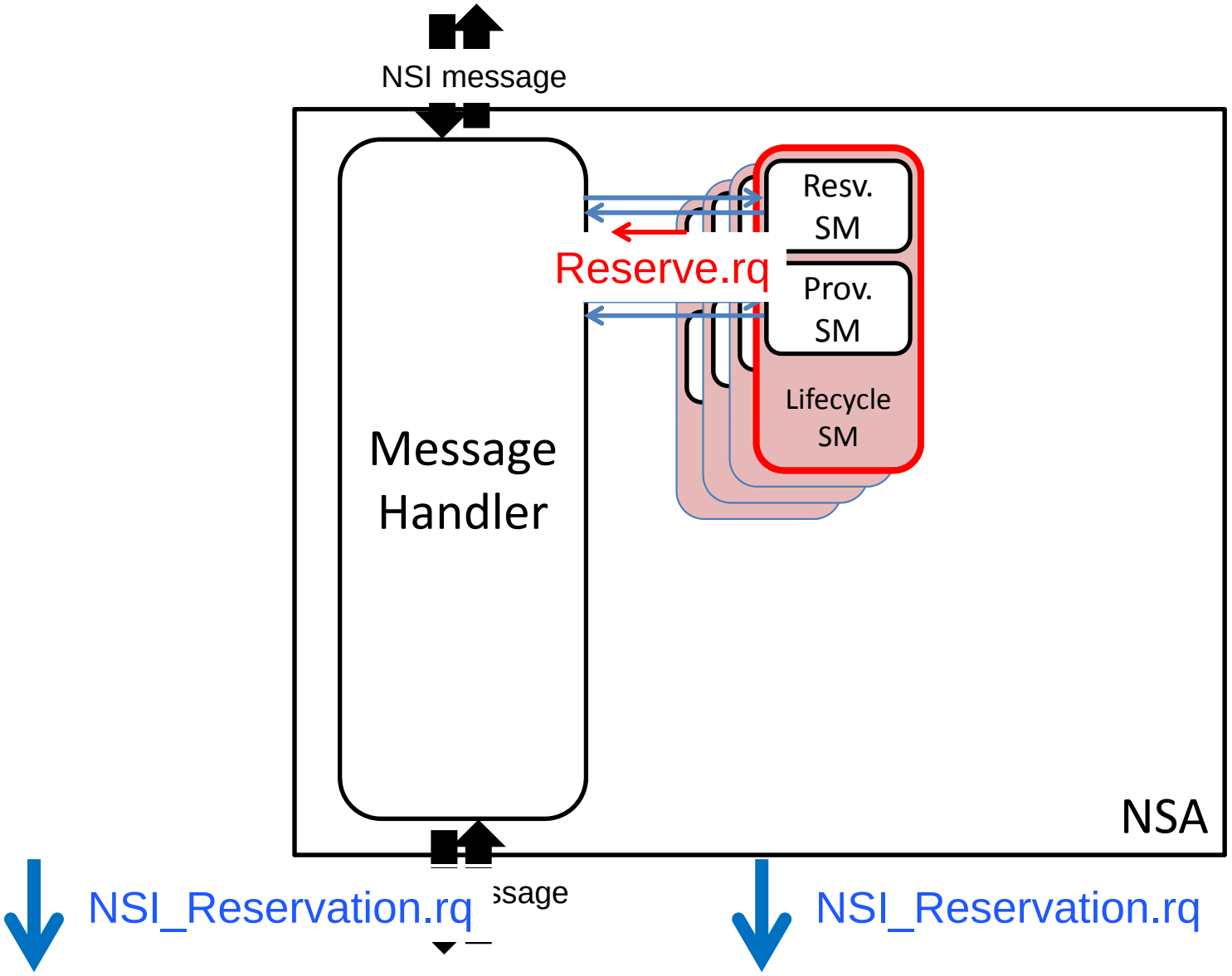
Transitional States

NB: Requests received in this state is queued and processed only when it transitions to a Stable State. *NB: Exceptions are term.rq and unexpected messages (e.g. illegal sequence)*

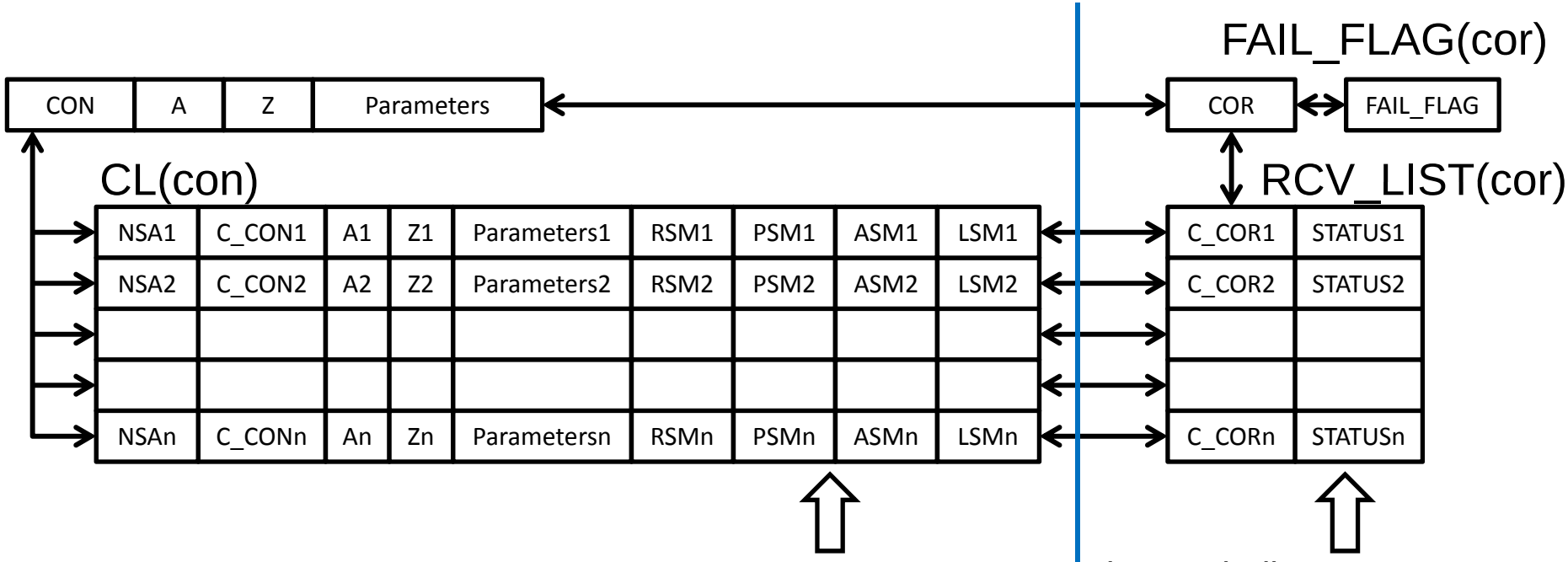
Stable States

Final State

Aggregator NSA

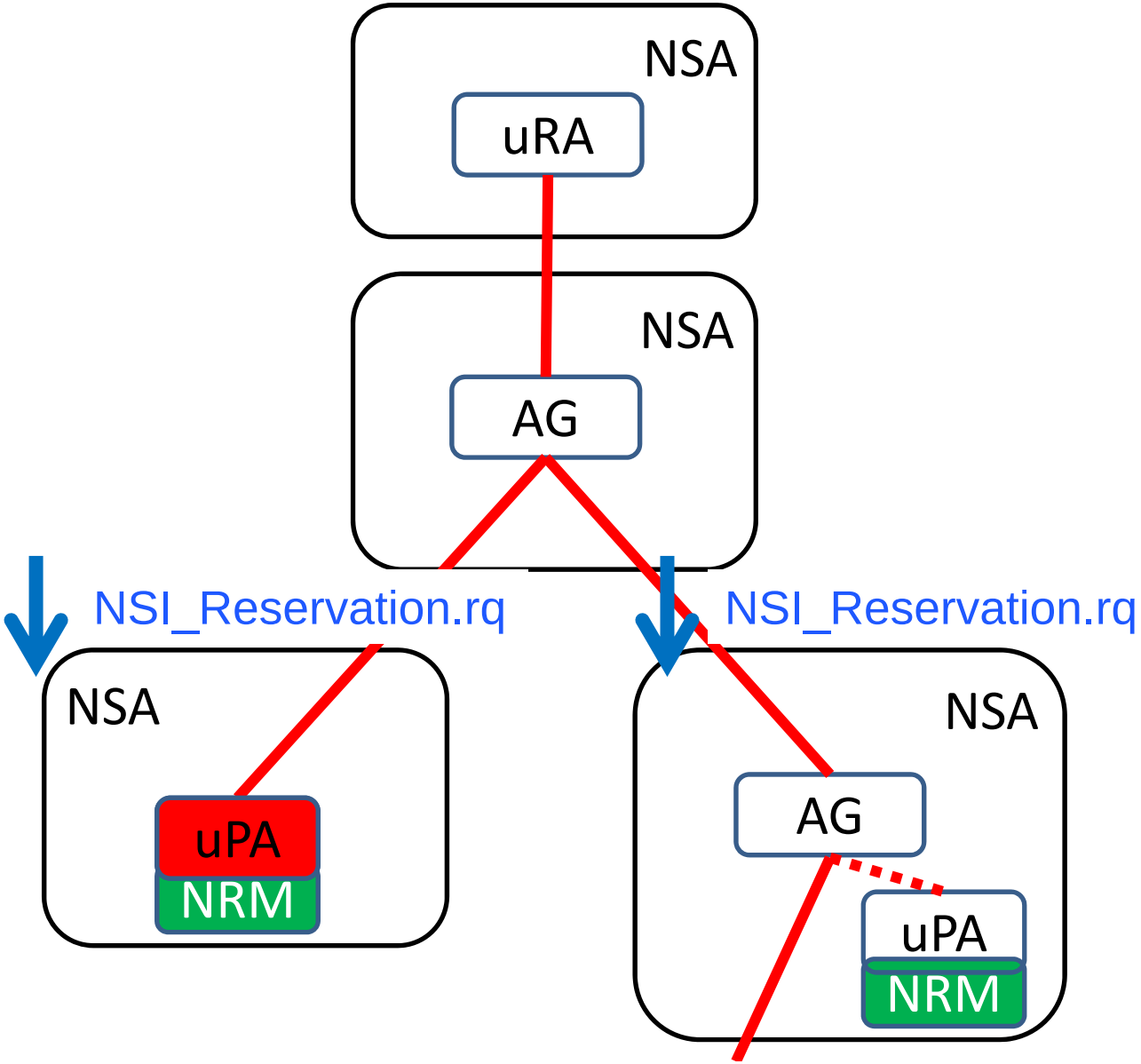


Tables an aggregator MH maintains for each reservation (connection)

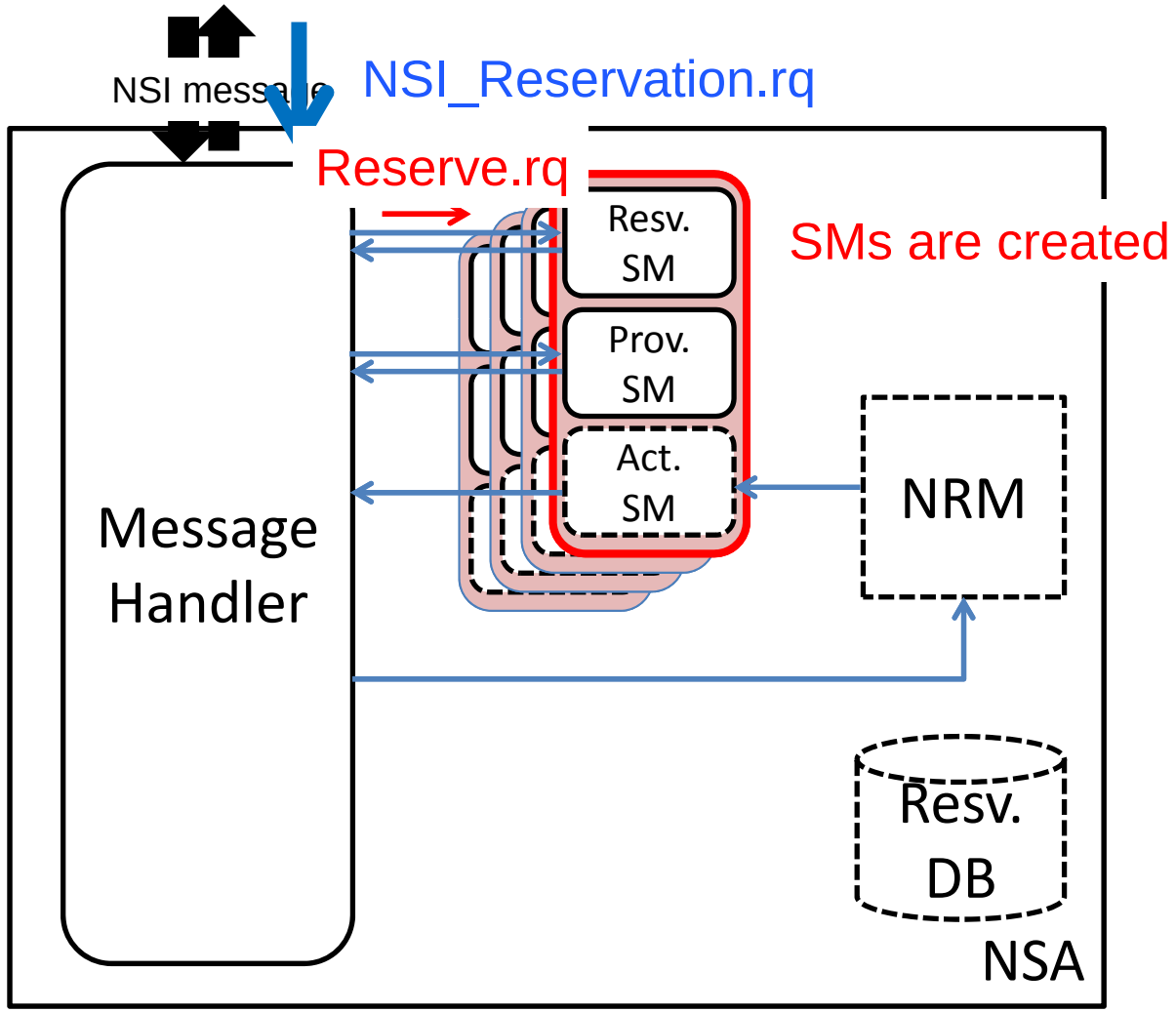


Generated for each reservation (connection)

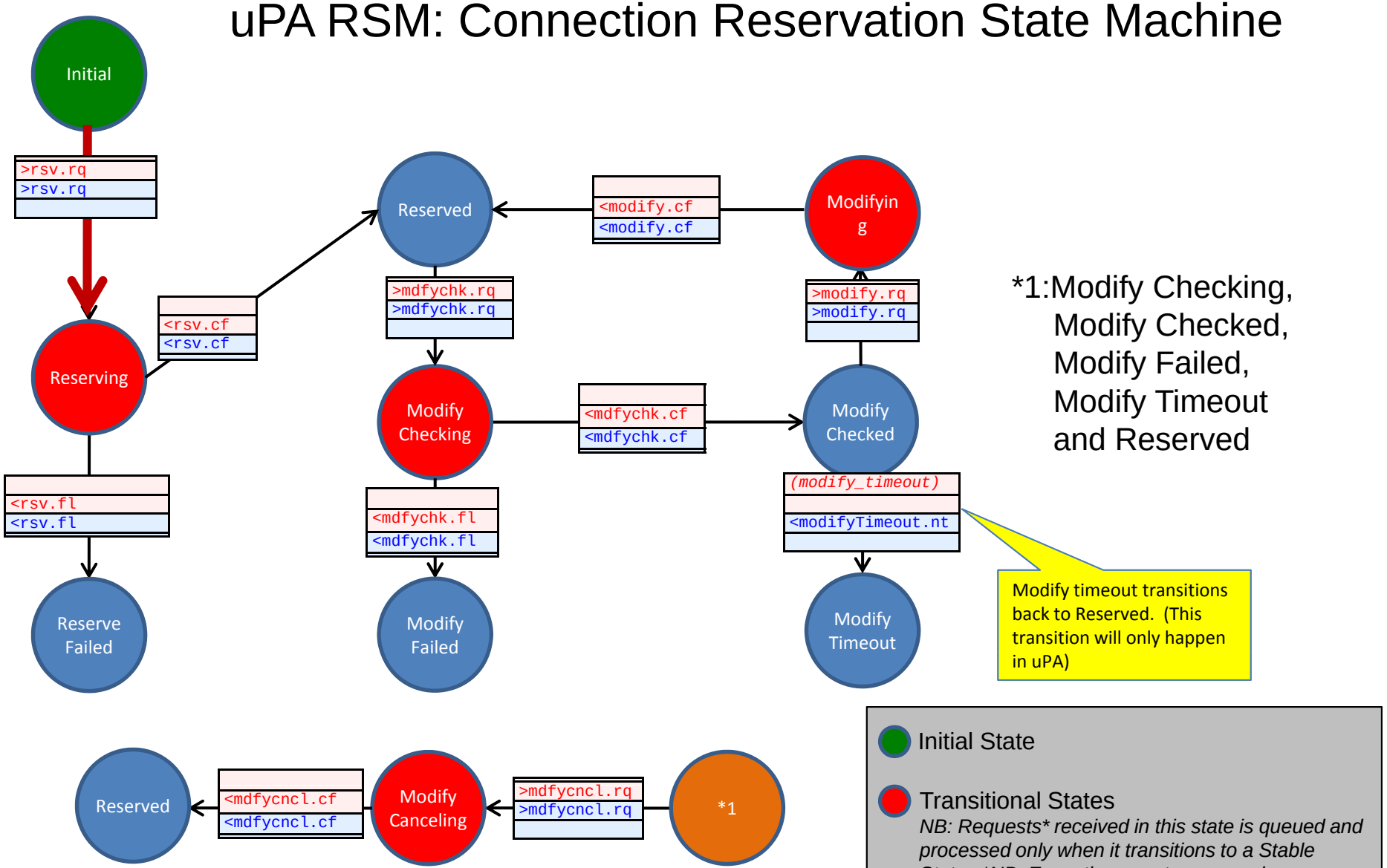
Generated for each request


NSA
uRA
NSA
AG
NSI_Reservation.rq
NSI_Reservation.rq
NSA
uPA
NRM
NSA
AG
uPA
NRM

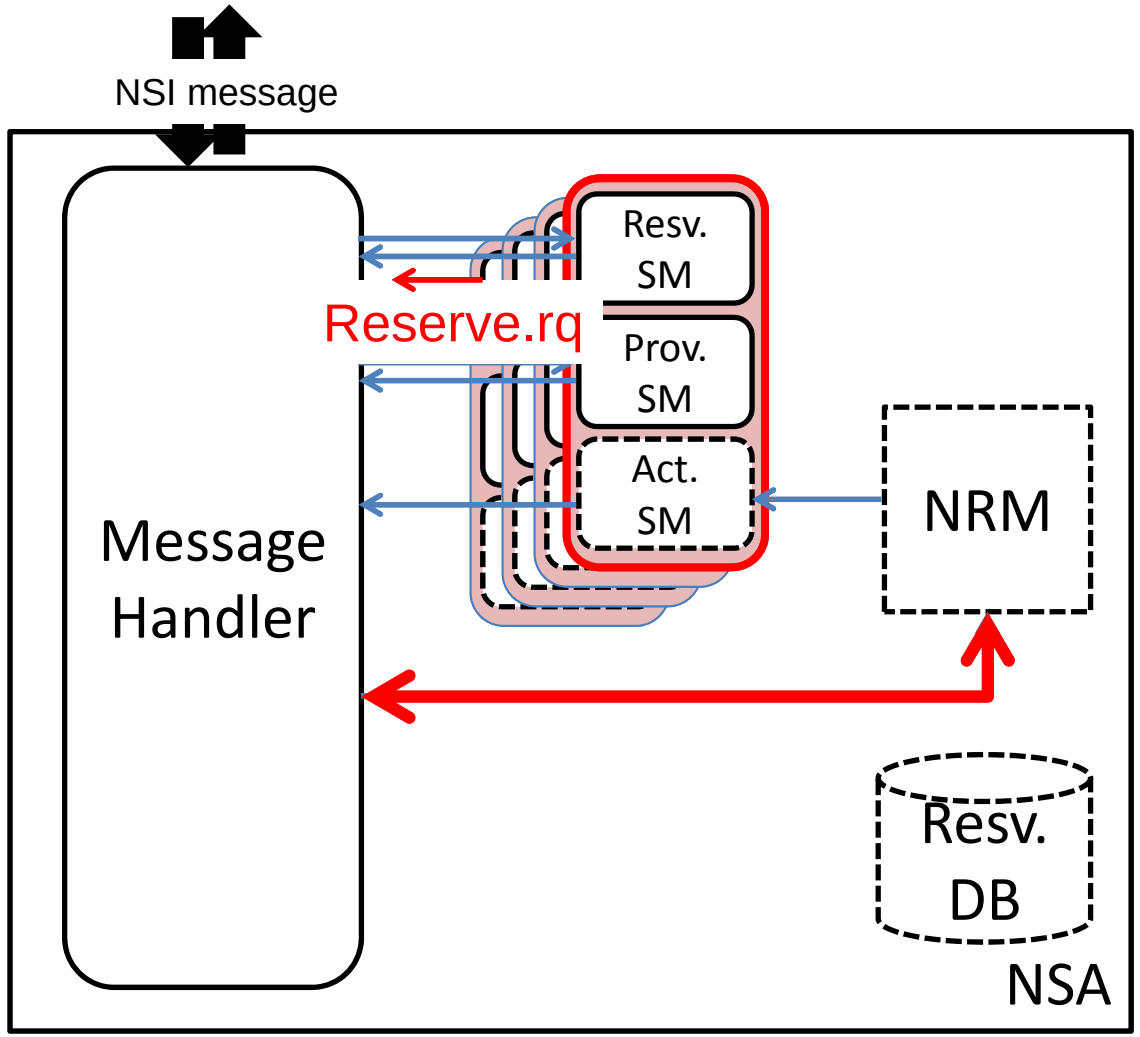
uPA NSA


NSI message
NSI_Reservation.rq
Reserve.rq
Resv. SM
Prov. SM
Act. SM
SMs are created
Message Handler
NRM
Resv. DB
NSA

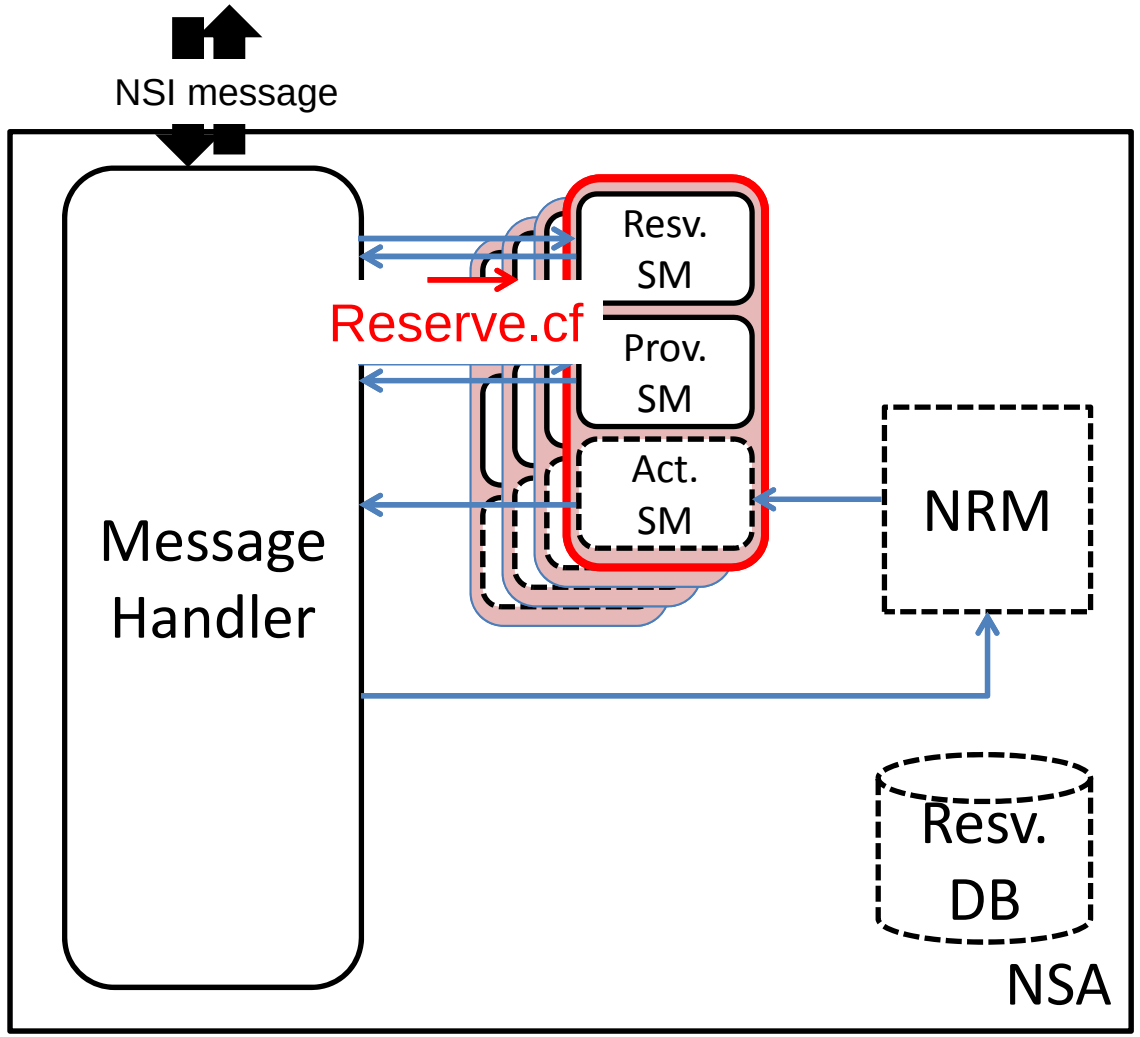
uPA RSM: Connection Reservation State Machine



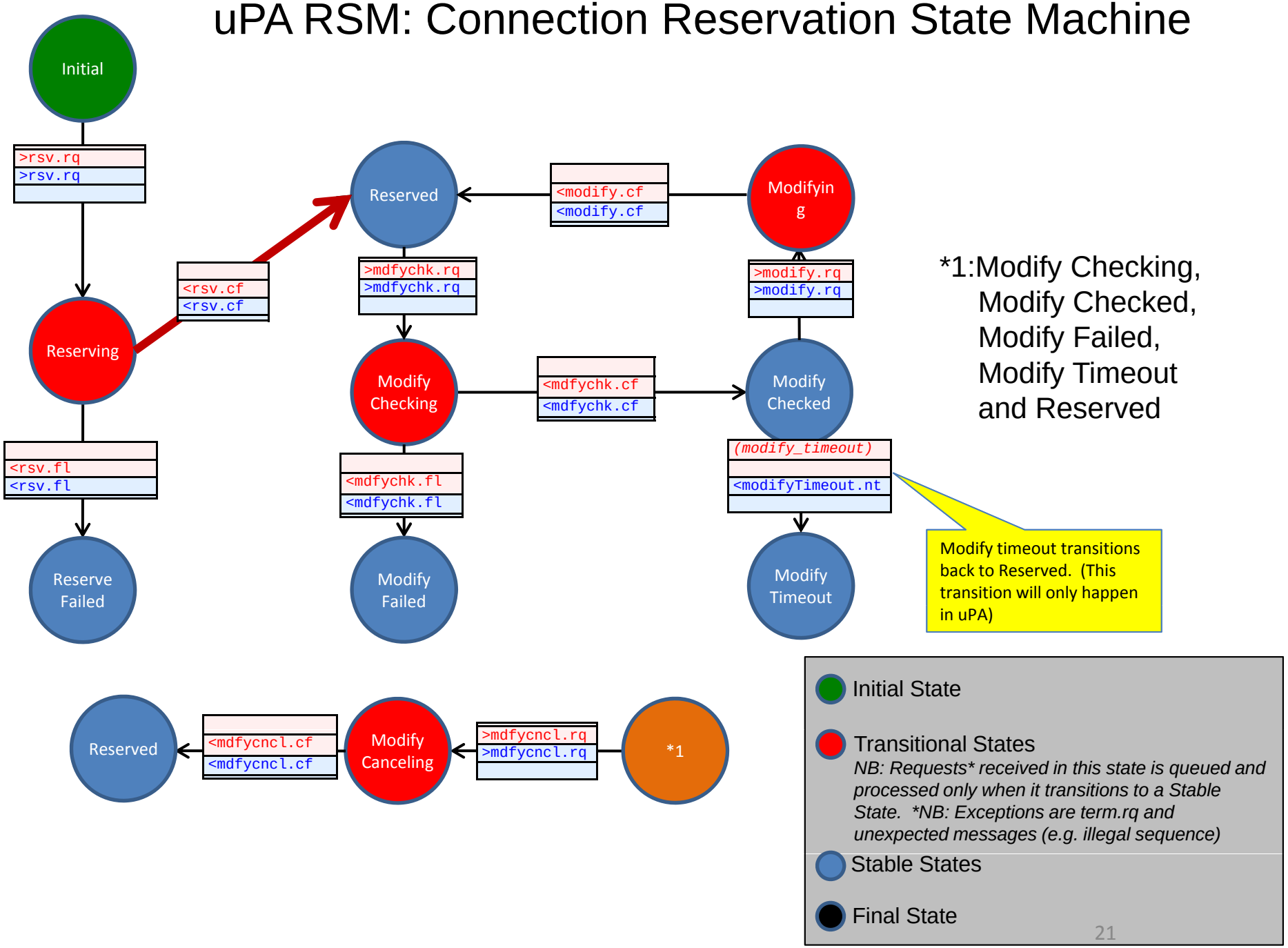
uPA NSA


NSI message
Resv.
SM
Reserve.rq
Prov.
SM
Act.
SM
Message
Handler
NRM
Resv.
DB
NSA

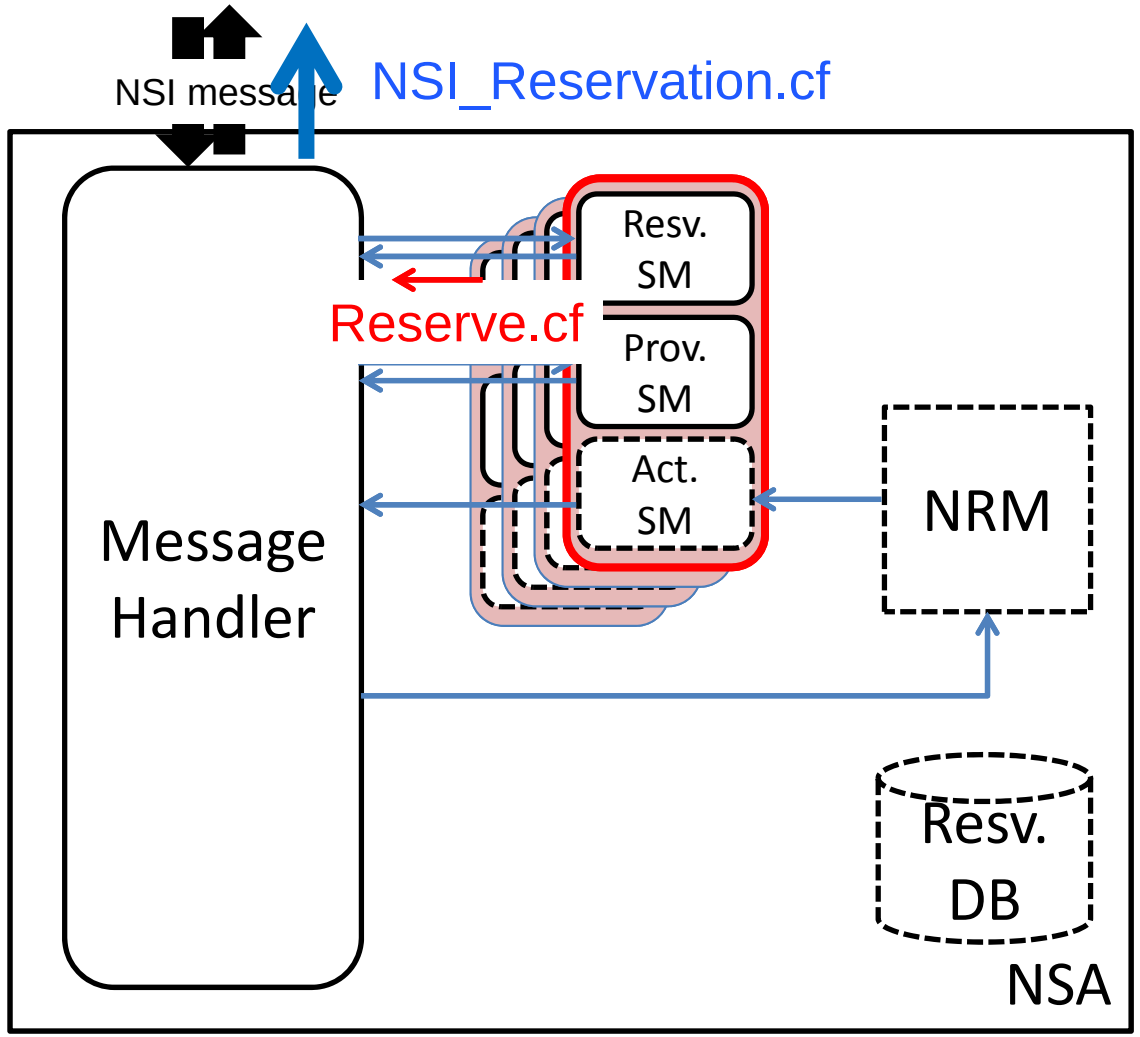
uPA NSA

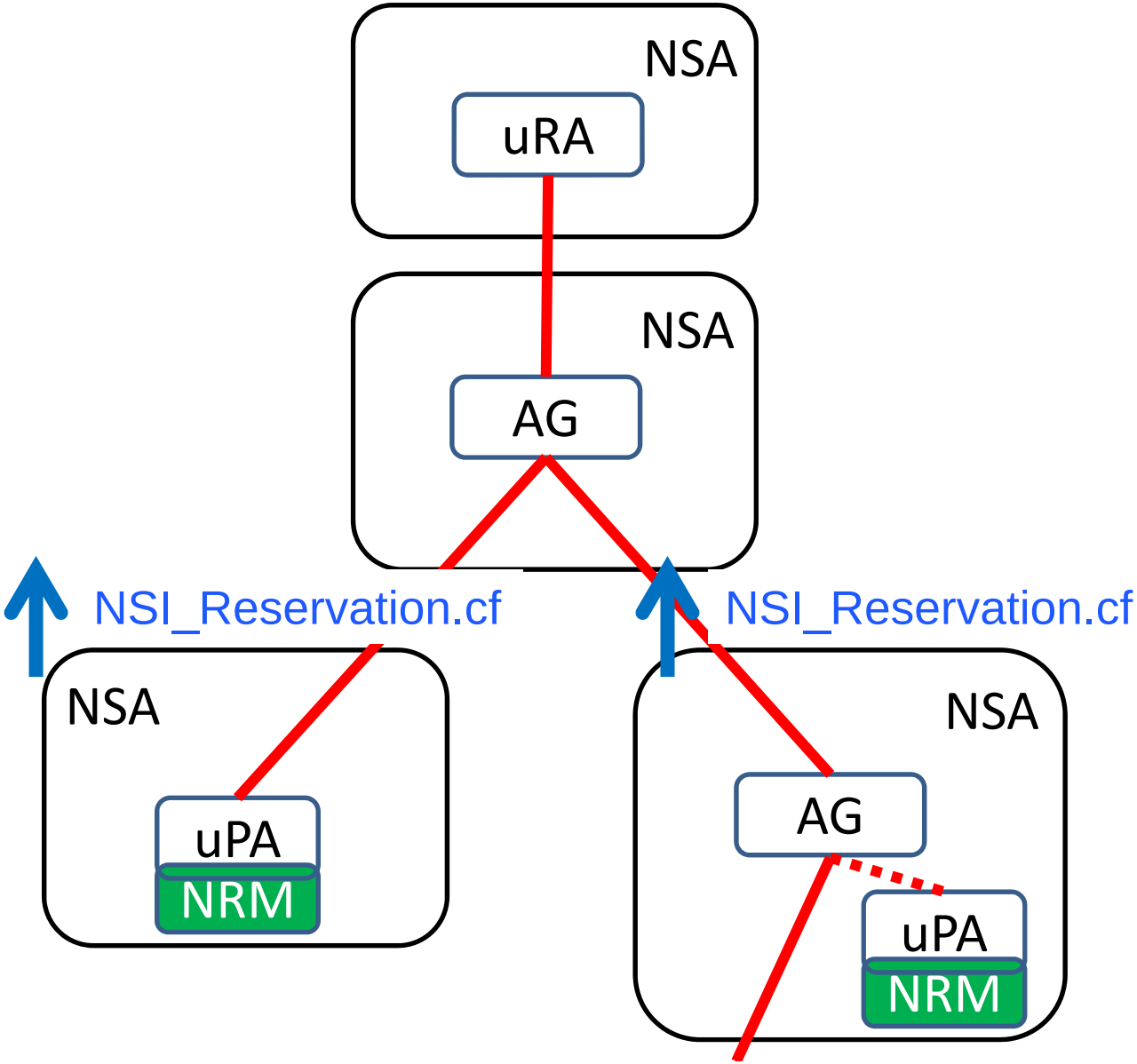

NSI message
Message Handler
Reserve.cf
Resv. SM
Prov. SM
Act. SM
NRM
Resv. DB
NSA

uPA RSM: Connection Reservation State Machine

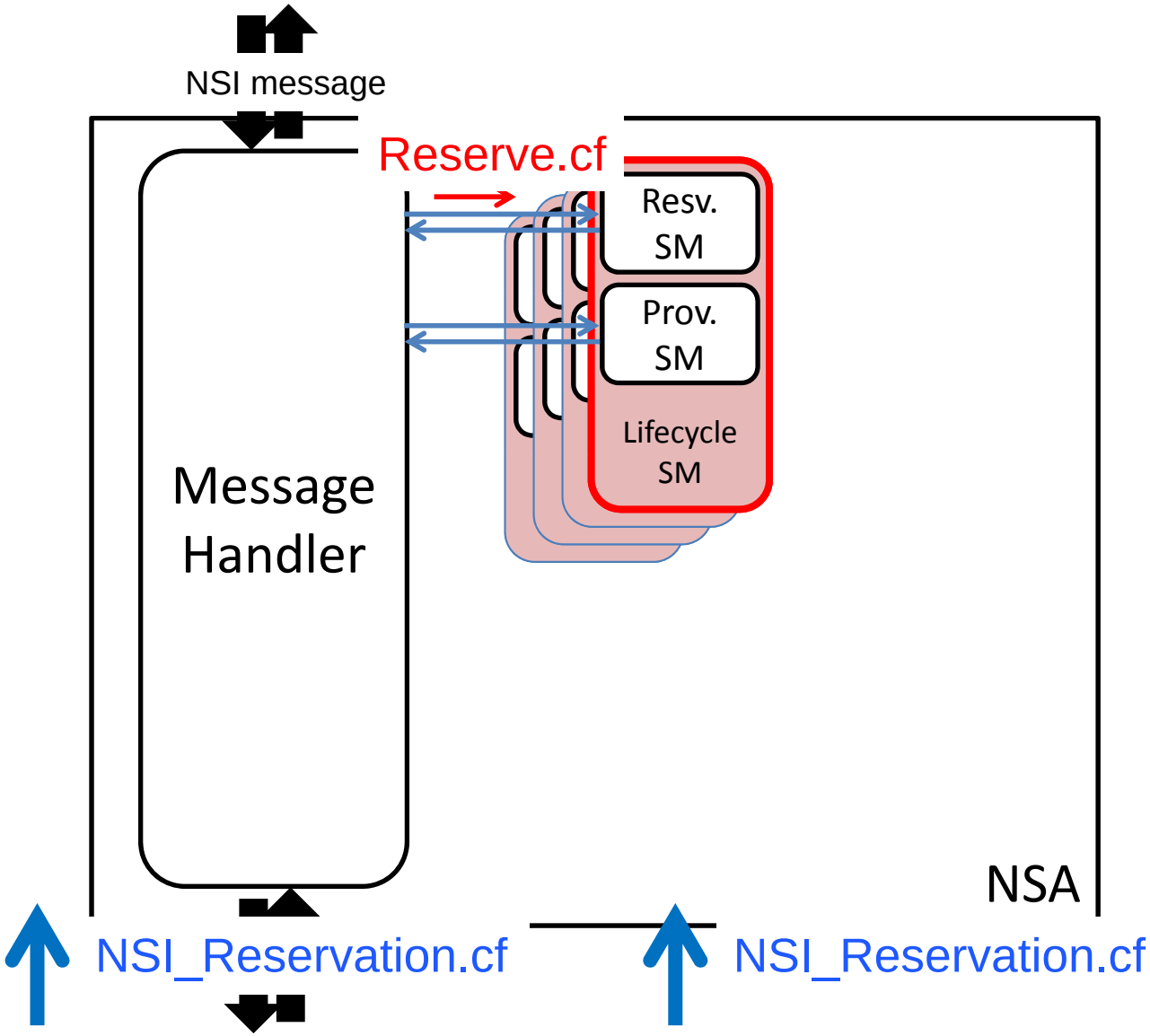


uPA NSA

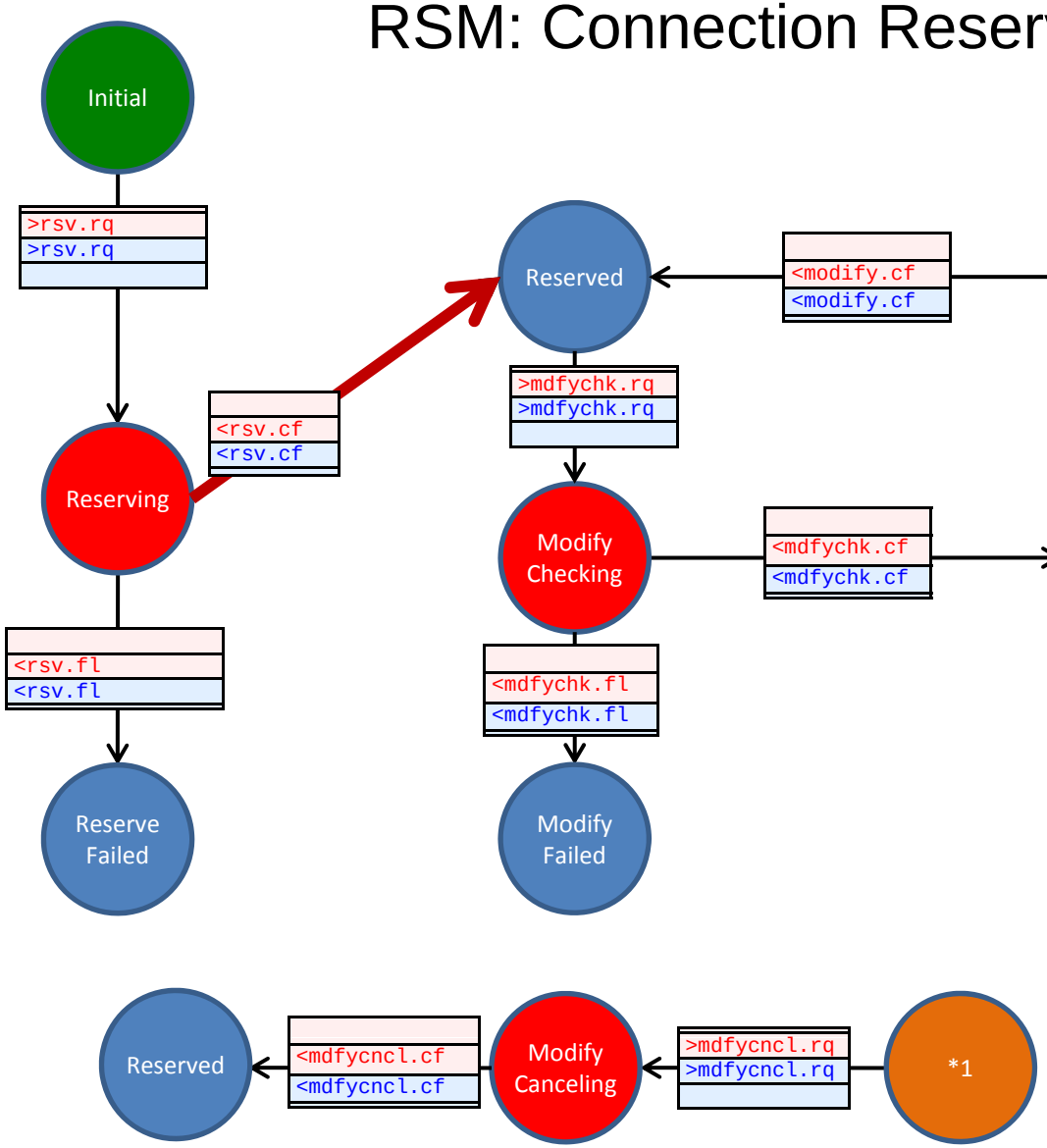

NSI message
NSI_Reservation.cf
Resv.
SM
Reserve.cf
Prov.
SM
Act.
SM
Message
Handler
NRM
Resv.
DB
NSA


NSA
uRA
NSA
AG
NSI_Reservation.cf
NSI_Reservation.cf
NSA
uPA
NRM
NSA
AG
uPA
NRM

Aggregator NSA



RSM: Connection Reservation State Machine



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Modify Timeout
and Reserved

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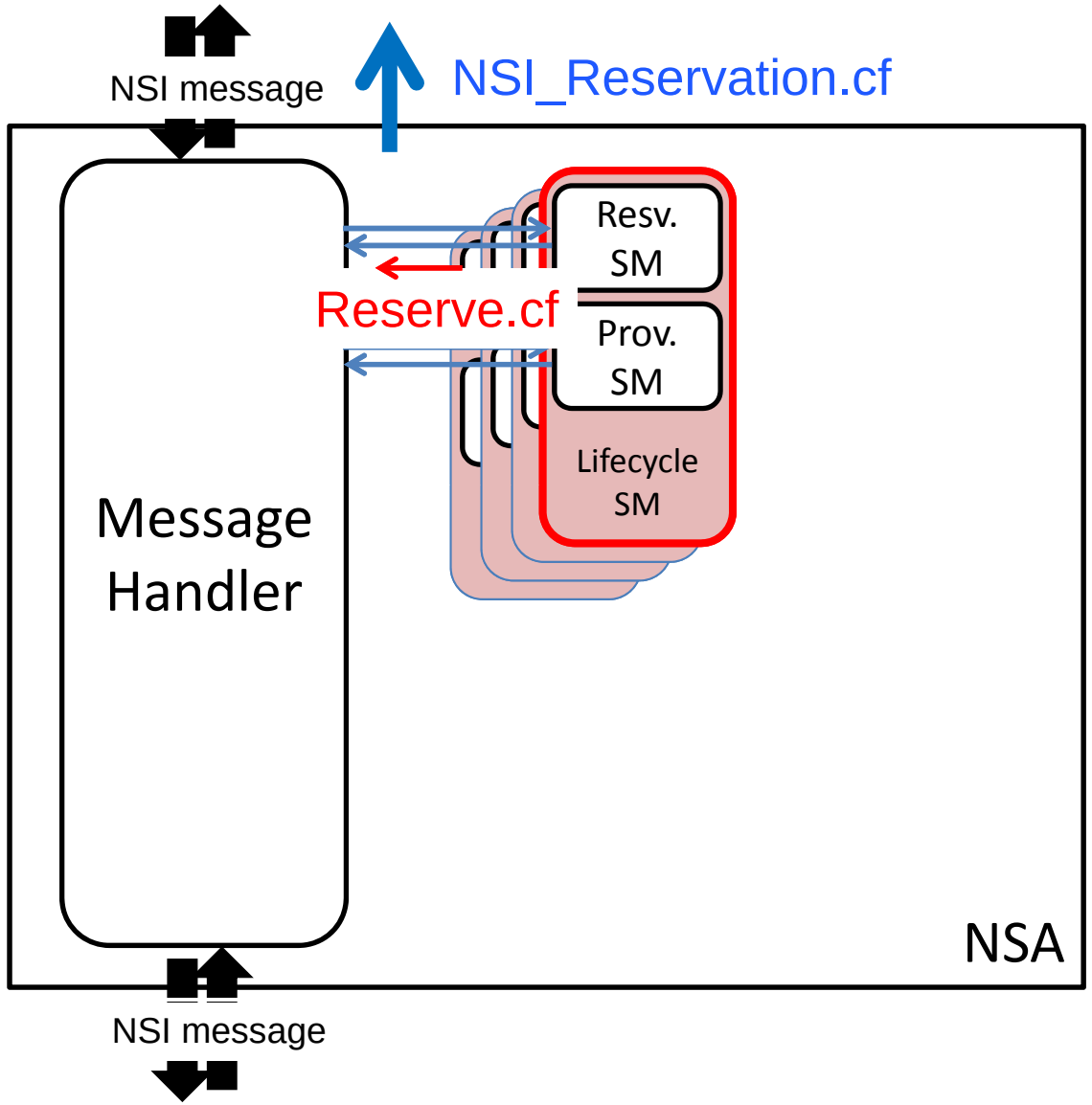
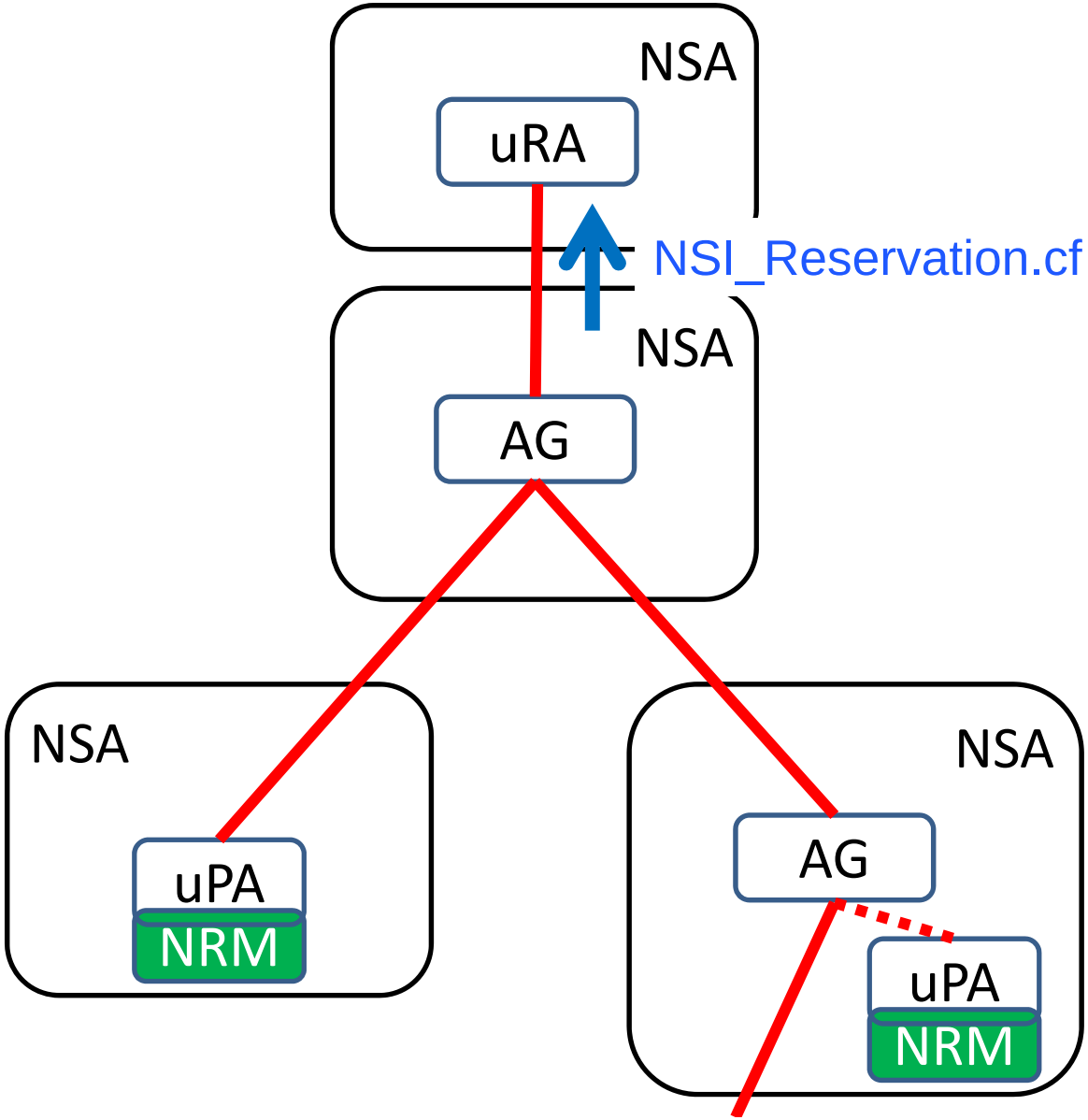
Stable States

Final State

Aggregator NSA

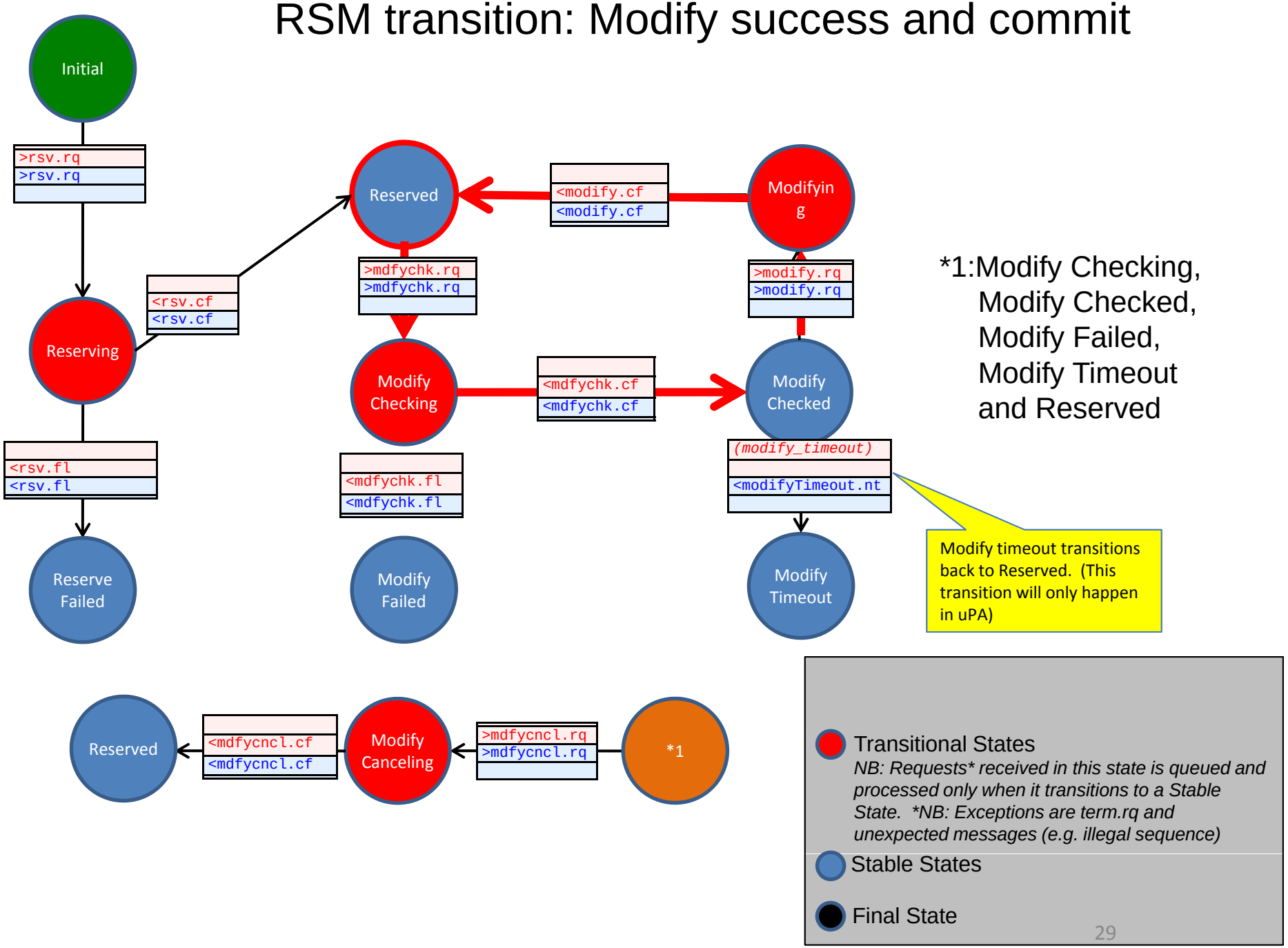



NSA
uRA
NSI_Reservation.cf
NSA
AG
NSA
uPA
NRM
NSA
AG
uPA
NRM

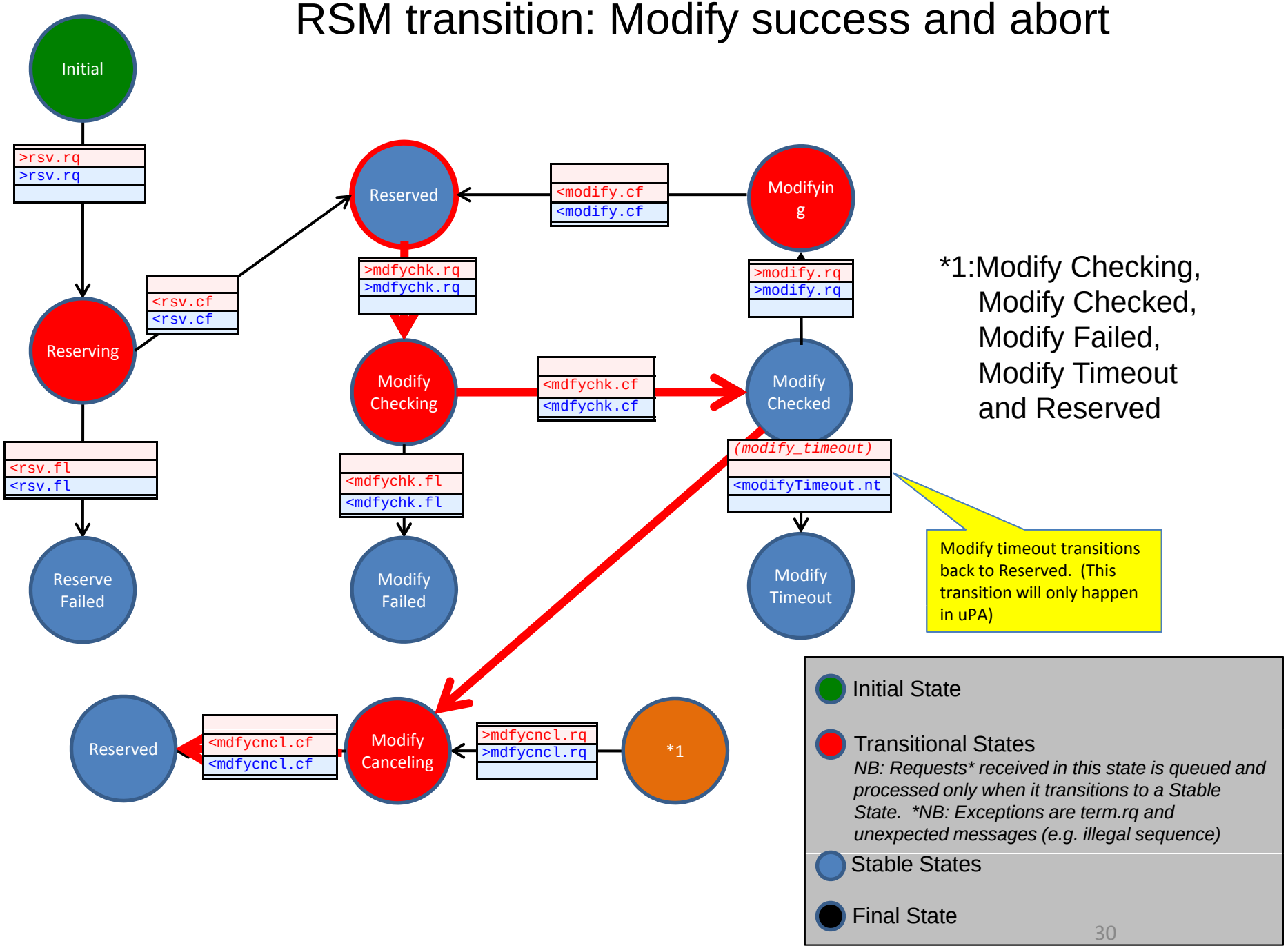
Modify

- Modify operations modify reservation
- Currently, following two changes are supported
  - Change end time of a reservation
  - Change bandwidth
- Modify is a 2-phase operation
  - 1: check availability (ModifyCheck.rq)
    - Note: resources are held
  - 2: Commit (Modify.rq) or Abort (ModifyCancel.rq)
- When committed, the reservation is updated
  - Reservation has a version number assigned by uRA, and the version number is updated when committed (uniformly increasing)

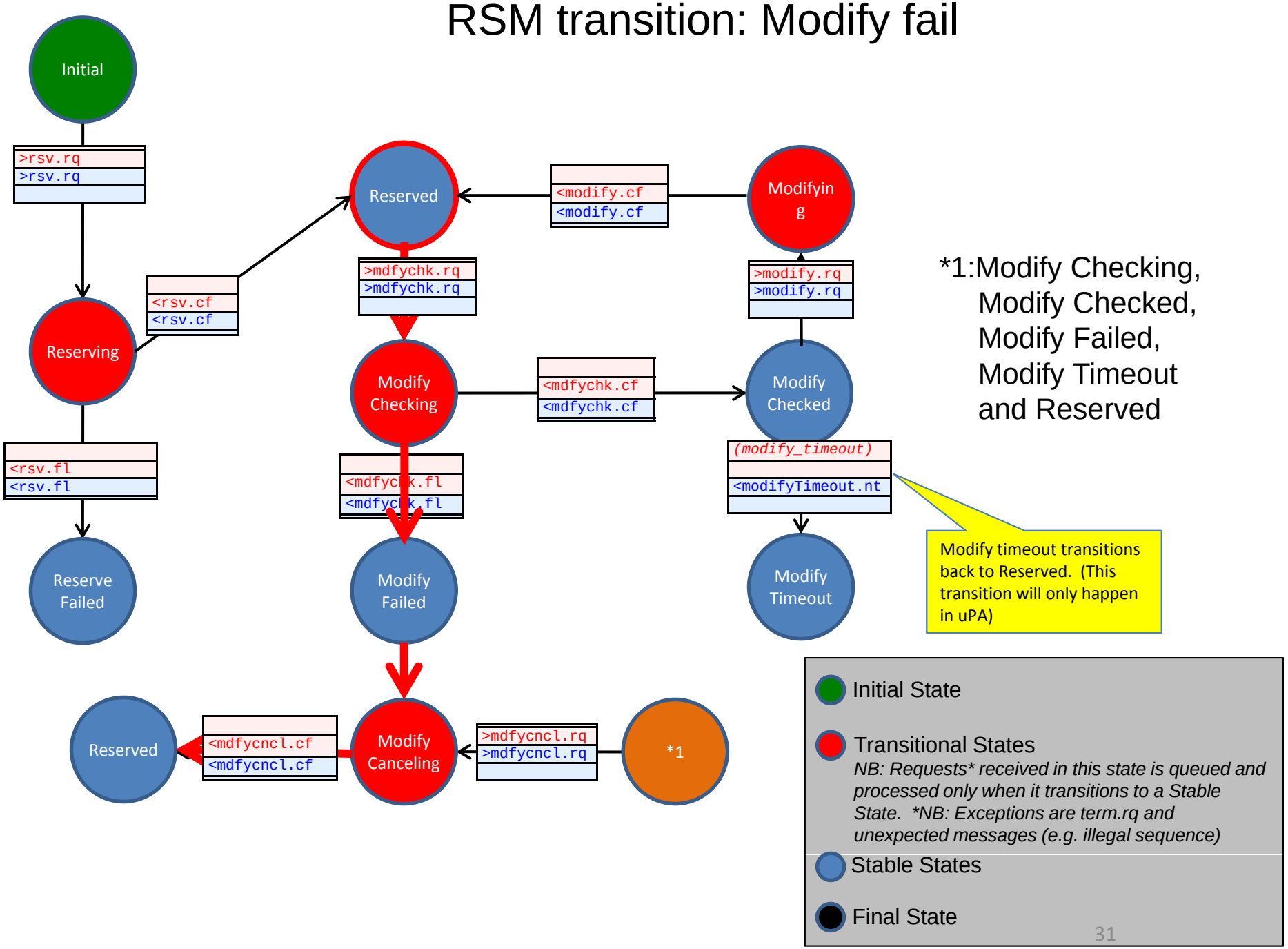
RSM transition: Modify success and commit



RSM transition: Modify success and abort



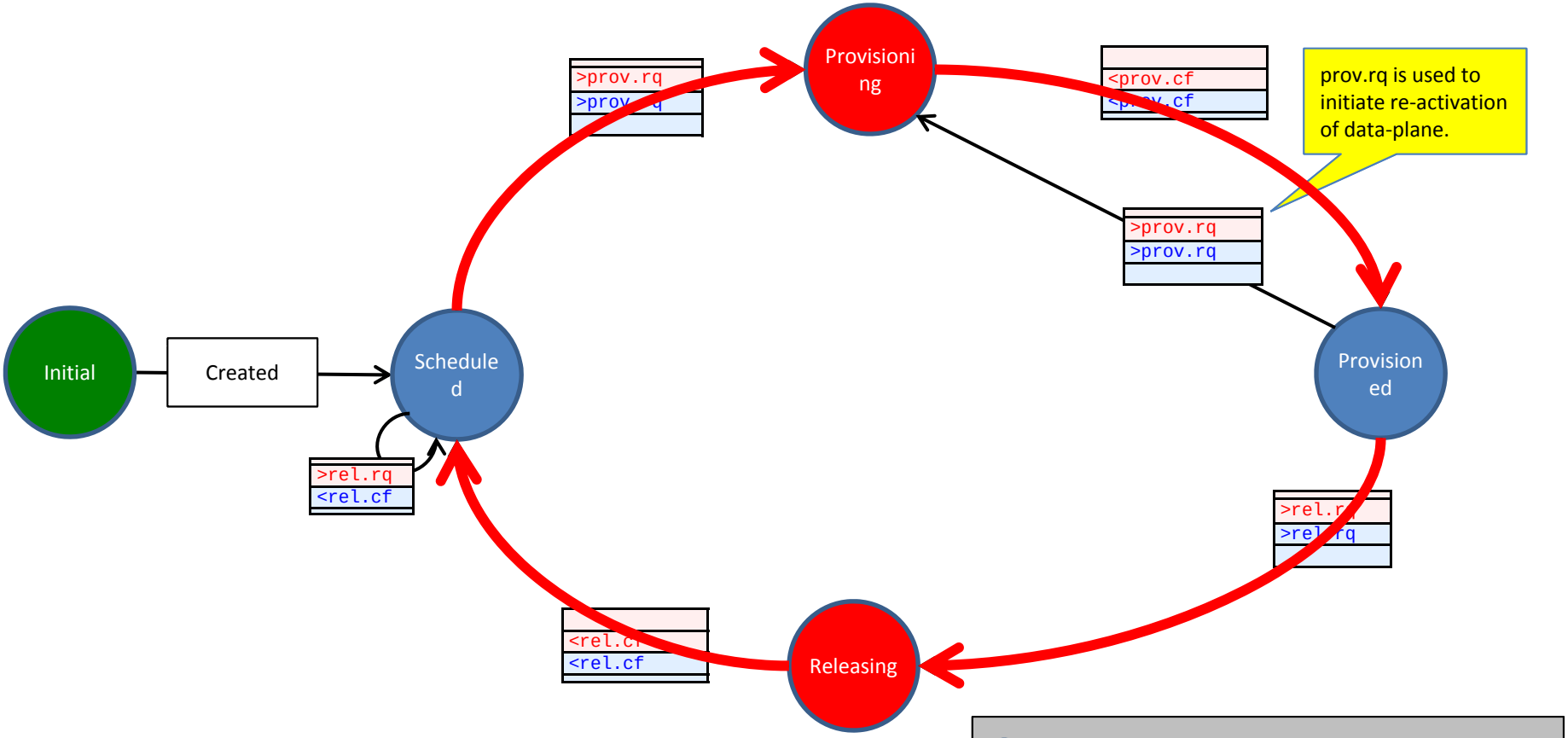
RSM transition: Modify fail



Provision and Release

- Provision state machine is independent from the reservation state machine
- Provision state:
  - Data plane should be activated if the PSM is in “Provisioned” state AND start_time < current_time < end_time
  - Data plane shall not be activated before the start_time
- A connection can be repeatedly provisioned and released

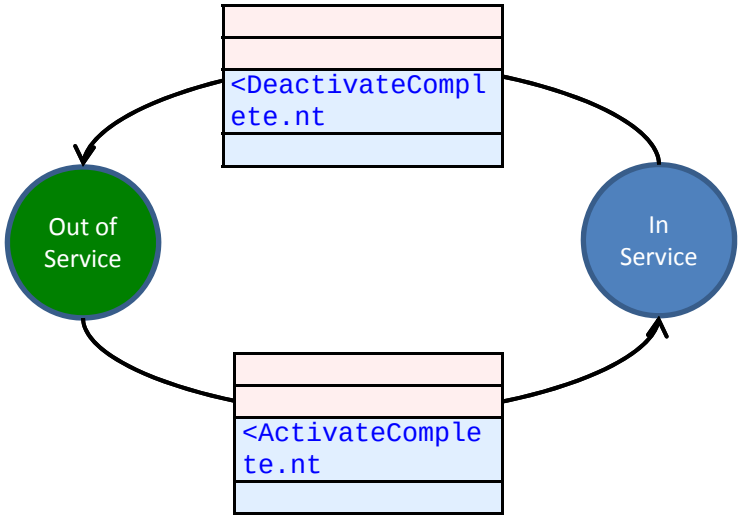
PSM : Connection Provision State Machine

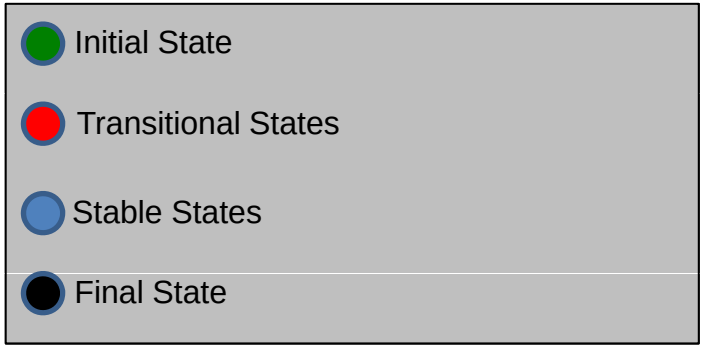


Data plane activation

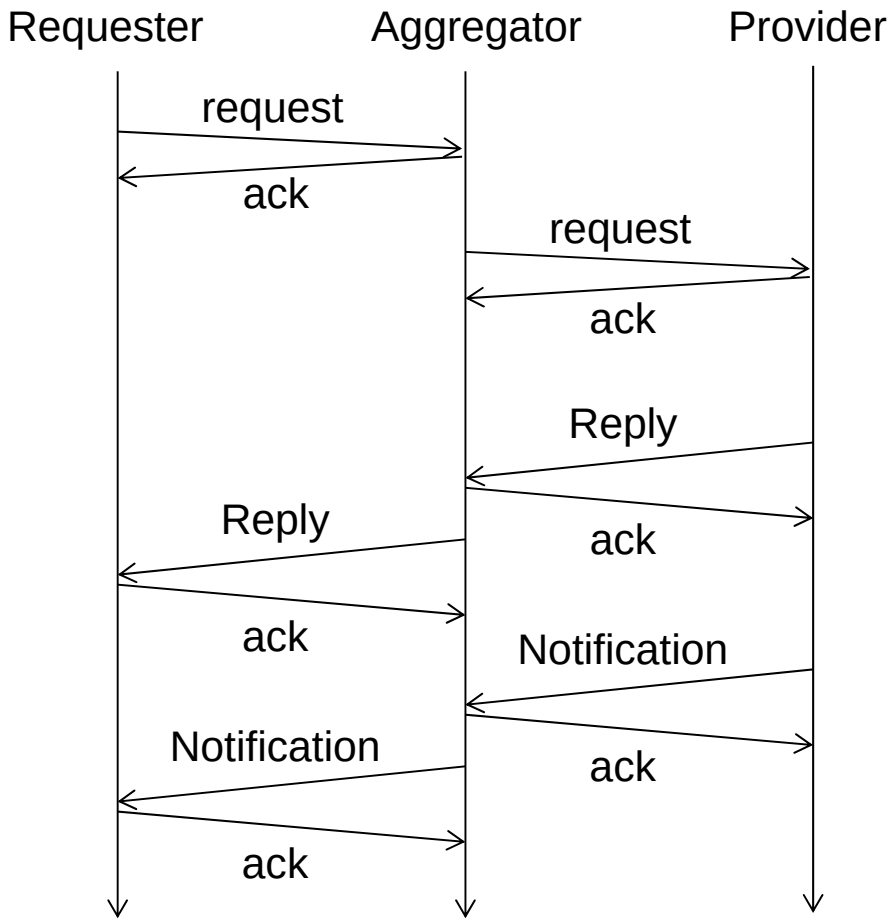
- Data plane should be activated if the PSM is in “Provisioned” state AND start_time < current_time < end_time
- Activation is done at the timing of following events (if the above condition is met), using the latest reservation information
  - PSM transits to “Provisioned”
  - At the start_time
  - Reservation is updated (by commit of modify)
  - Data plane is recovered from an error
- Data plane activation/deactivation are notified by notification messages

ASM : Connection Activation state machine





Message ack and reply



- Ack is sent by MTL for each message
  - If ack is not returned in a certain period of time, MTL timeout occurs
- Reply is sent by MH and either confirm, fail or not_applicable
  - MH can timeout if expected reply is not received from a child

Notifications: Activation related

- Activation notify messages
  - NSI_activateFailed.nt
  - NSI_activateComplete.nt
  - NSI_deactivateComplete.nt
  - NSI_deactivateFailed.nt
  - NSI_dataplaneError.nt
  - NSI_forcedEnd.nt
- At aggregators, notifications are handled and sent up by MH. RSM and PSM are not affected by notifications.

Requests which can fail

- Operations which can functionally fail are:
  - Reserve.rq
  - ModifyCheck.rq
  - Those requests fail when requested resources are not available.
- Other operation cannot fail. However, they can timeout in MTL, or can be denied because they are invalid requests.
  - If a SM is at a state in which the request cannot be received, the request is denied.
    - *.na (not applicable) message is returned.

Timeouts

- Modify timeout
  - After NSI_modifyCheck.rq is confirmed (succeeded), it should be either committed (modify.rq) or aborted (modifyCancel.rq)
  - Since resources are held while waiting for modify.rq or modifyCancel.rq, uPA cannot wait forever. So it can timeout, and send up NSI_modifyTimeout.nt
- Message transport layer (MTL) timeout
  - Underlying MTL (http/tcp) initiates a MTL timeout
  - Happens when an ack is not returned for a request.
- Message Handler (MH) timeout
  - MH can timeout if a reply message is not returned in a certain period of time

modifyCancel after timeout

- After modifying operations, if a NSA is already in RESERVED state, it can receive NSI_modifyCancel.rq and reply NSI_modifyCancel.cf, but the modification is not rolled back. The system may be in an inconsistent state (different versions across the system) after those operations.

Notifications: modify timeout and MTL failure

- NSI_modifyTimeout.nt
- NSI_genericEvent.nt
  - Message delivery failure will be notified by this message (to be defined)
- When a MTL/MH timeout is notified, uRA can either retry or terminate the connection.
  - Retry is requested by NSI_messageRetry.rq, which has the original request message's id (correlation id) as a parameter

Termination and LSM

- A connection lifecycle is terminated when NSI_terminate.rq is received.
- LSM (Lifecycle State Machine) handles the terminate request.
  - Terminate request will delete the RSM, PSM and ASM, but the LSM should be there to send/receive terminate request and confirm messages
  - uPA may delete RSM, PSM and ASM when it isseues fcd_end, but LSM cannot be deleted.

LSM : Connection Life Cycle state machine