SIMMOD Course Notes

September 29, 2002

Prepared by AirportTools from a hardcopy of a document of the same title supplied by the FAA, with some minor modifications.

What is SIMMOD?

An advanced, state-of-the-art computer model.

Simulates both airfield and airspace traffic operations.

A flexible powerful tool capable of calculating capacity, travel time, delay and fuel consumption.

Designed to plan improvements by "playing out" alternatives in operations, technologies or facilities.

Why Use SIMMOD?

Feasible

Cheaper

Safer

Purpose of SIMMOD

Provide answers.

Help make decisions.

Improve decision-making ability.

SIMMOD's History

Development of the Airport! Airspace Delay Model (ADM) (1978-1979)

Development of SIMMOD by adding to ADM an airfield model and a fuel consumption model (1980-1982)

Modification and enhancement of the SIMMOD simulation and development of pre- and post -processors (1983-date)

Validation of the SIMMOD Simulation Model (1985-date)

Application of SIMMOD to address "real-world" capacity and delay problems (1987 -date)

SIMMOD's Future

Continued development with improvements and enhancements supported by various private organizations and government agencies.

Training and complete documentation.

User groups, internet support, and mailing lists.

SIMMOD Studies

Runway operations.

Airfield ground operations.

Terminal traffic.

Multi-airport interactions.

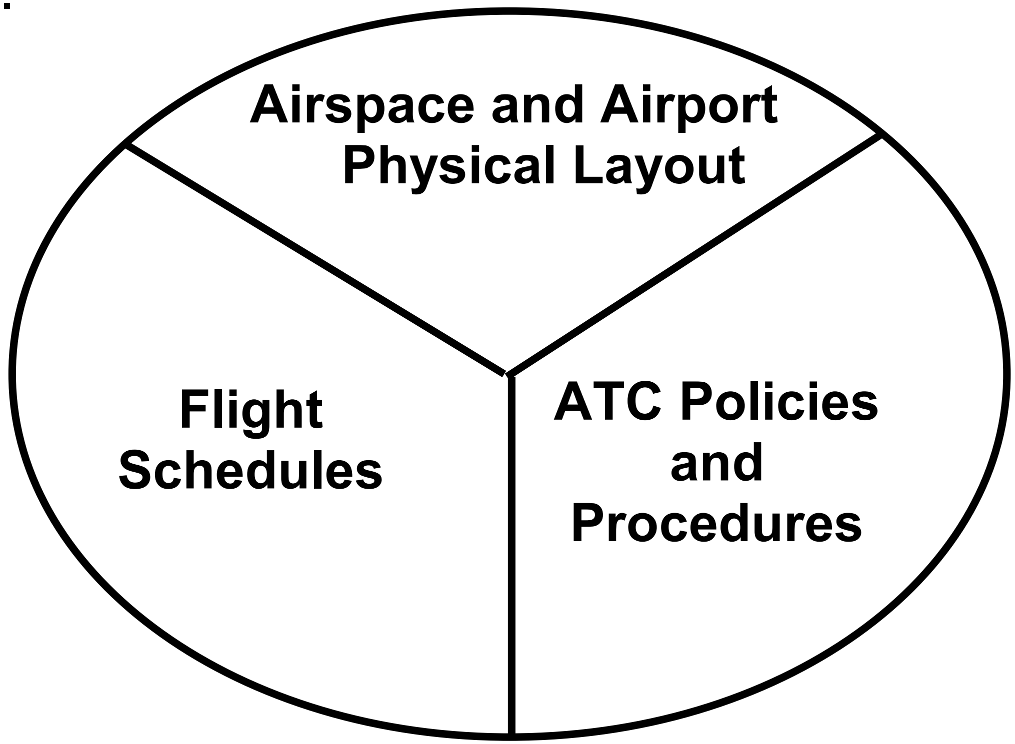
En route airways.

SIMMOD Addresses

ATC policies and procedures.

Airport and airspace physical layouts.

Flight schedules.



How SIMMOD Works

Builds airspace and airports from inputs.

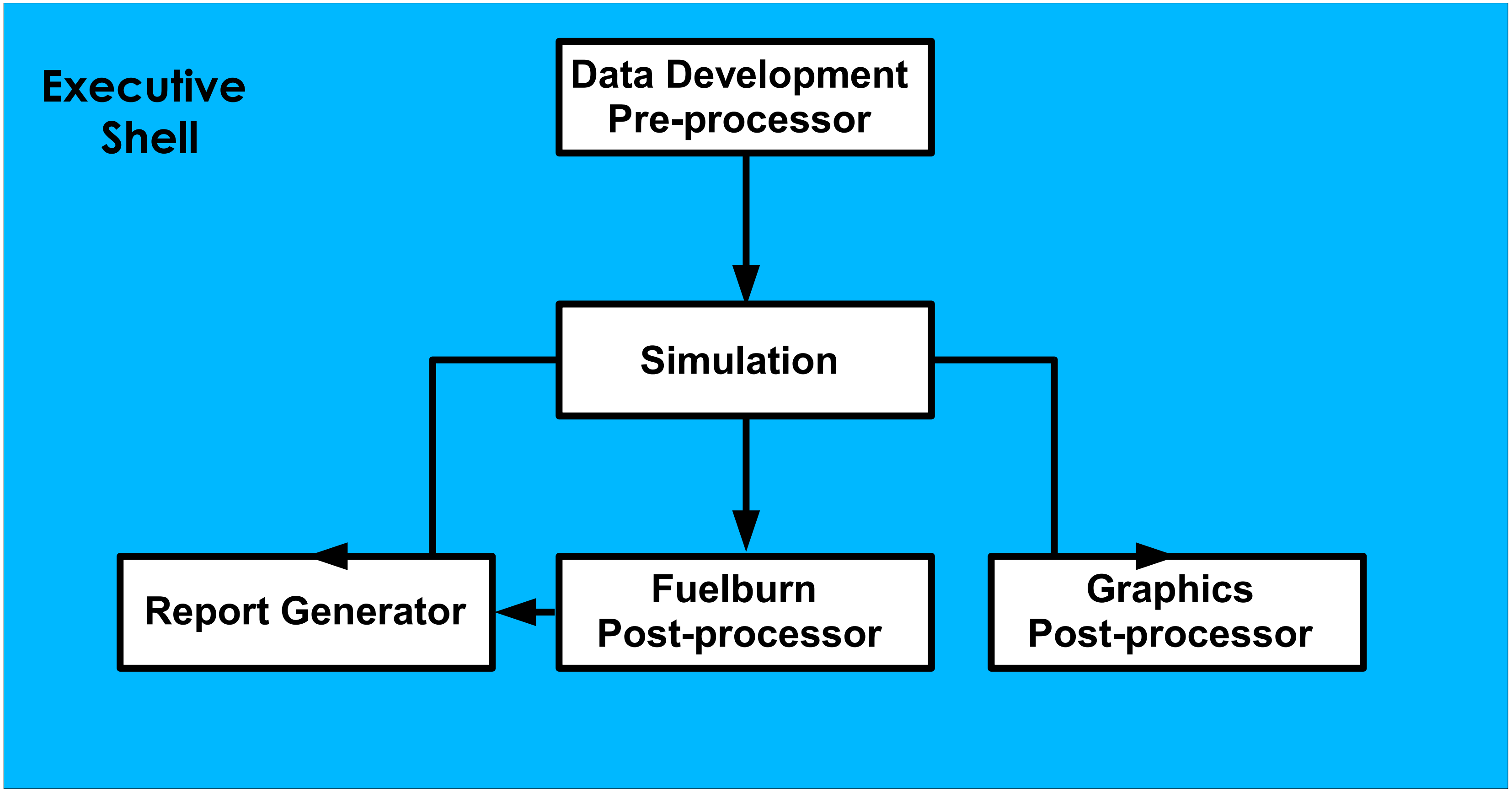
Simulates all flights.

- Uses external data to initiate flights.
- Resolves all conflicts.

Generates reports of all outputs required for study.

- Reports come in several types.
- Report types are determined by input.

SIMMOD System



Executive
Shell

Data Development
Pre-processor

Simulation

Report Generator

Fuelburn
Post-processor

Graphics
Post-processor

SIMMOD Simulation is Event-Stepped

The simulation moves from one scheduled event to the next.

The simulation clock is based on the current event's scheduled initiation, not elapsed clock time.

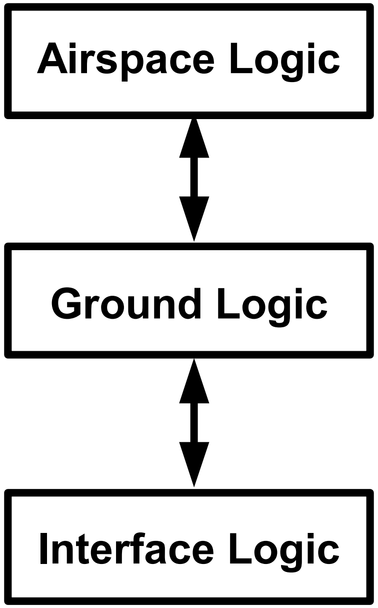
Events that are simultaneous, i.e., events with the same initiation times, are processed sequentially but there is no time change to the simulation clock.

SIMMOD Logic

Airspace logic.

Ground logic.

Interface logic.



Airspace Logic

Ground Logic

Interface Logic

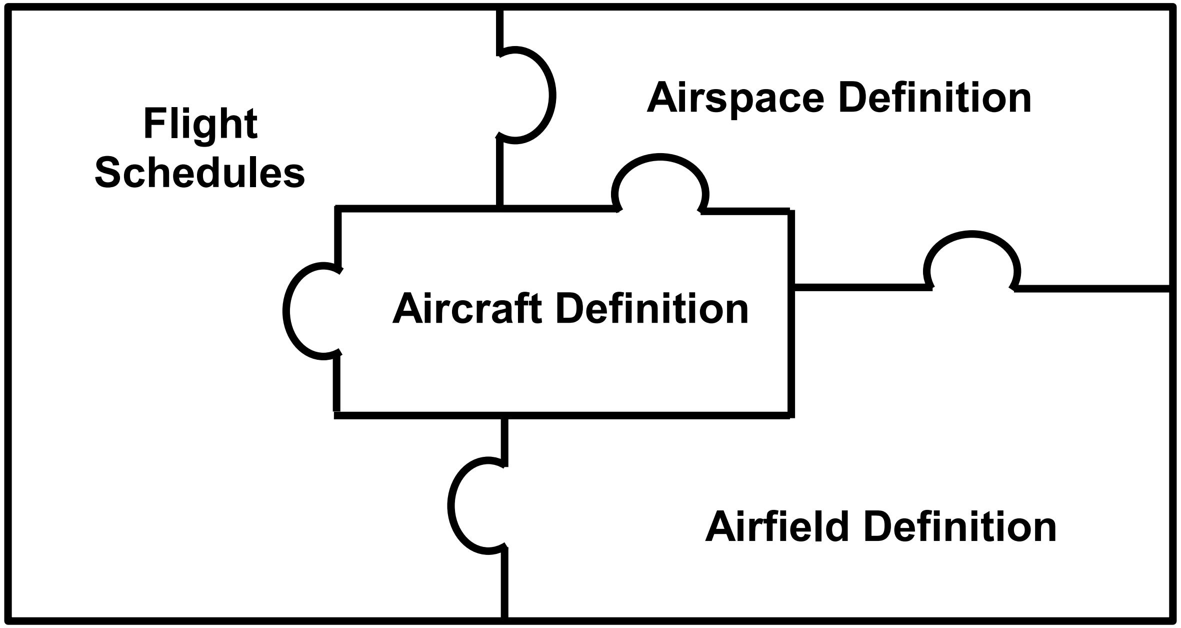
SIMMOD Inputs

Airspace definition.

Airfield definition.

Aircraft definition.

Flight schedule.



SIMMOD Data File Basics

Data is read free format.

Data can be printed as output.

Data can include comments for future reference.

SIMMOD Measures

Capacities.

Travel times.

Delays.

Fuel consumption.

SIMMOD Outputs

Runway Flows and Demands by:

- Arrivals vs. Departures
- Aircraft types and totals
- Runways
- Hourly

Travel times by:

- Arrivals vs. Departures
- Travel vs. Delay
- Air vs. Ground
- Hourly

Airspace Logic

Airspace network:

- The structure the simulation works within to move aircraft in the air.

Aircraft movement in airspace:

- Basic aircraft movement.
- Holding.
- Merging aircraft.
- Metering.
- Flow control.

Airspace Network

A route is made up of nodes and links.

- Each route is unidirectional.
- A node is a point in airspace where aircraft control is determined.
- A link is the minimum distance that an aircraft can travel between two nodes.

Airspace Nodes

Defined as a point in three dimensional space.

May correspond to a navigational fix.

May be a point where a change in altitude or direction is required.

Each node has a set of attributes including:

- Holding characteristics.
- Strategy for handling traffic flow.

Airspace Links

A path between two nodes.

Aircraft can only travel one direction on an airspace link.

Each link has a set of attributes including:

- Capacity.
- Link type that defines max, min, and nom speeds.

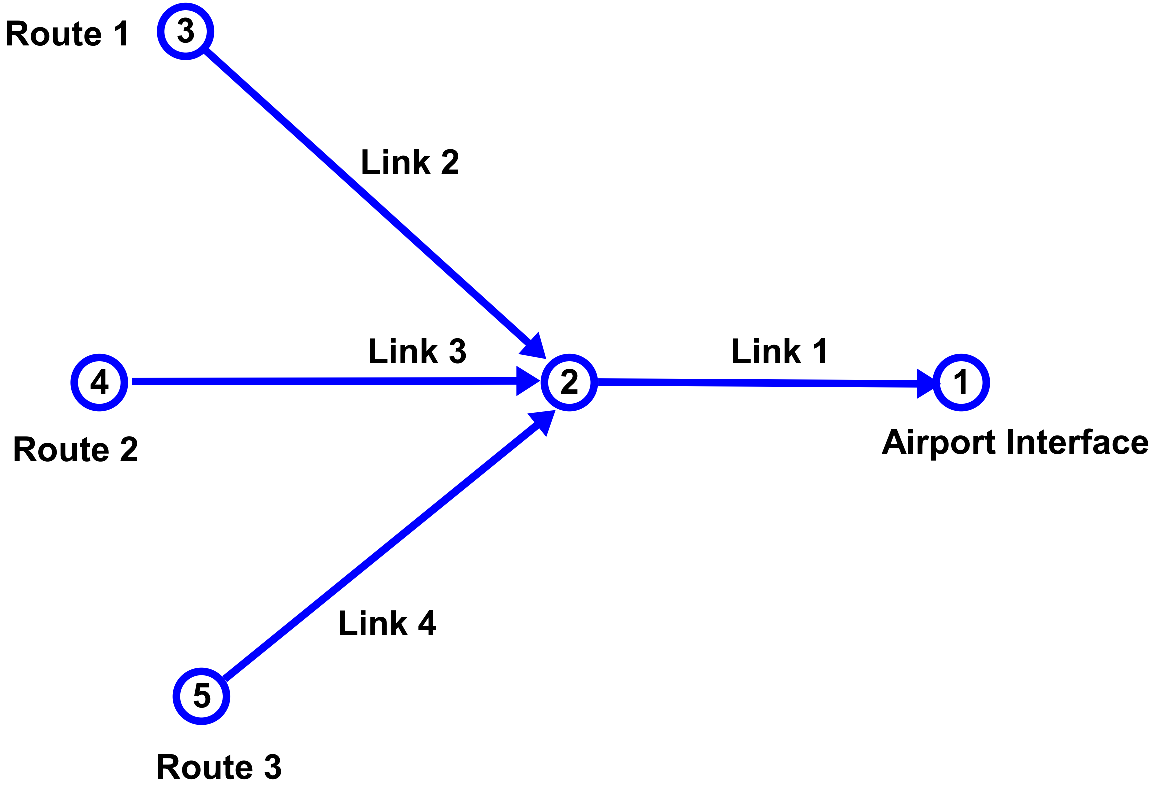
Airspace Routes

A set of ordered nodes between an origin node and a destination node.

Each route has a set of attributes including:

- Path of missed approach.
- Adjustment due to plan changes.

Terminal Airspace



Airspace Movement

Rules:

All movement is done on links.

An aircraft must maintain intrail separation with aircraft preceding it on a link.

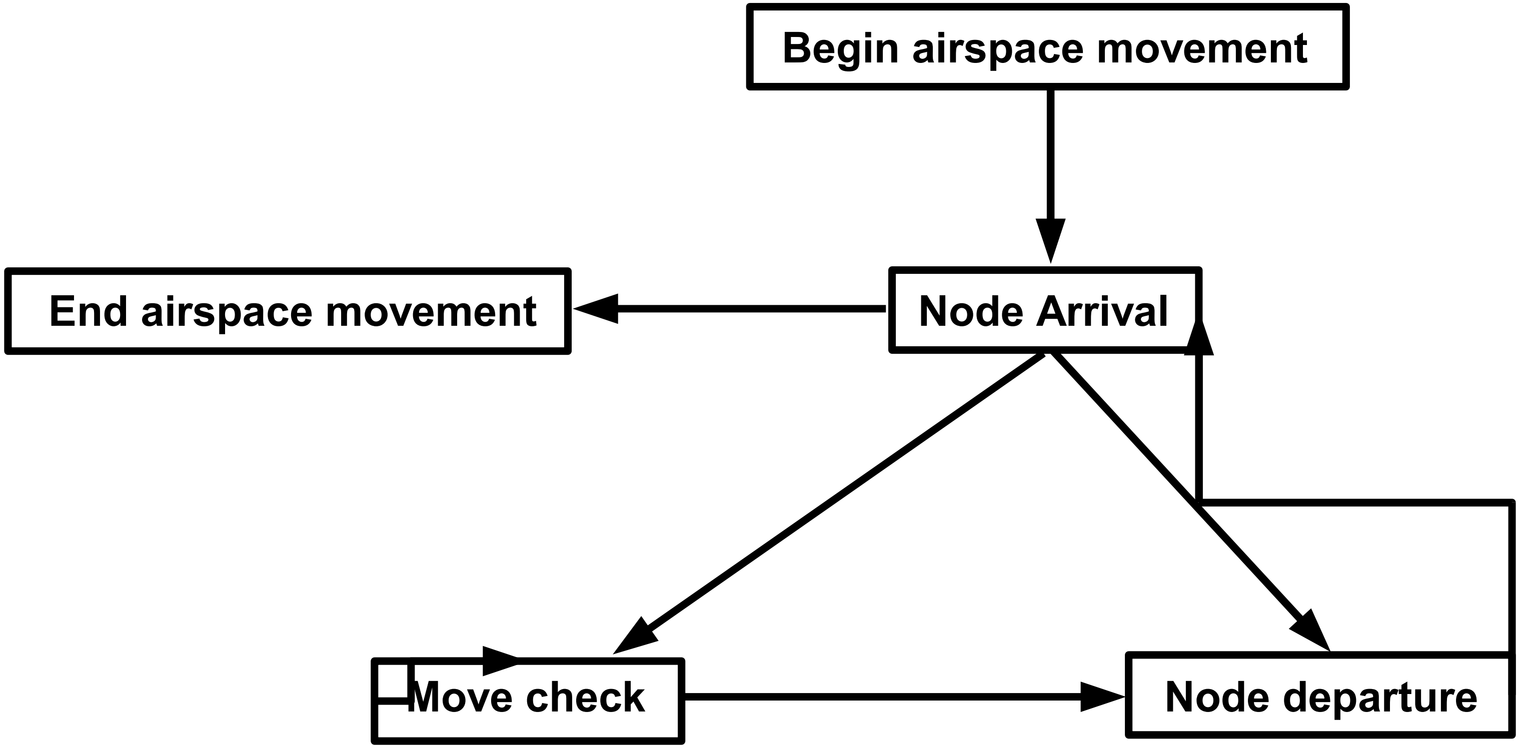
An aircraft must travel within defined speed ranges for its aircraft type.

Light /Heavy sequencing is optional on each link.

Passing of aircraft is optional on each link.

Vectoring of aircraft is optional on each link.

Airspace Movement



Begin airspace movement

End airspace movement

Node Arrival

Move check

Node departure

Node Arrival

Scheduled

- At a node when:
  - An aircraft starts a route.
  - An aircraft transitions from a takeoff at an airport.
  - An aircraft traverses from a previous node along a link.

Determines

- Basic holding for each aircraft at arrival to the current node, based on:
  - Holding at current node.
  - Holding strategy at the next node.
  - link capacity for the link connecting the current node and the next node.

Move Check

Scheduled

- **At a node by:**
  - **Aircraft arriving at current node.**
  - **Aircraft departing current node.**
  - **Estimated release time for aircraft in holding queue at the current node.**
  - **Aircraft departing from an approaching node to current node.**
  - **Aircraft leaving holding queue from an approaching node to current node.**

Determines

- **An aircraft's possible release from the node's holding queue, based on:**
  - **End of the scheduled hold delay for aircraft.**
  - **No wake turbulence conflict.**
  - **Hold increment for exiting holding stack.**

Node Departure

Scheduled

- **For an aircraft at a node when:**
    - **Aircraft arrives at a node.**
    - **After a hold delay at a node.**

Determines

- **Where an aircraft fits in the next node's arrival queue, based on that node's:**
    - **Arrival strategy.**
    - **Aircraft currently in its arrival queue.**

Aircraft Holding

Rules :

Holding is always done at a node.

Holding is last resort for solving a conflict between approaching aircraft.

Holding is done in FIFO queue.

The current node can ignore its own holding capacity.

The first node on a route has no holding strategy and infinite capacity.

Nodes where holding occurs actually occupy space to allow safe aircraft handling in the holding stack.

Holding Strategies

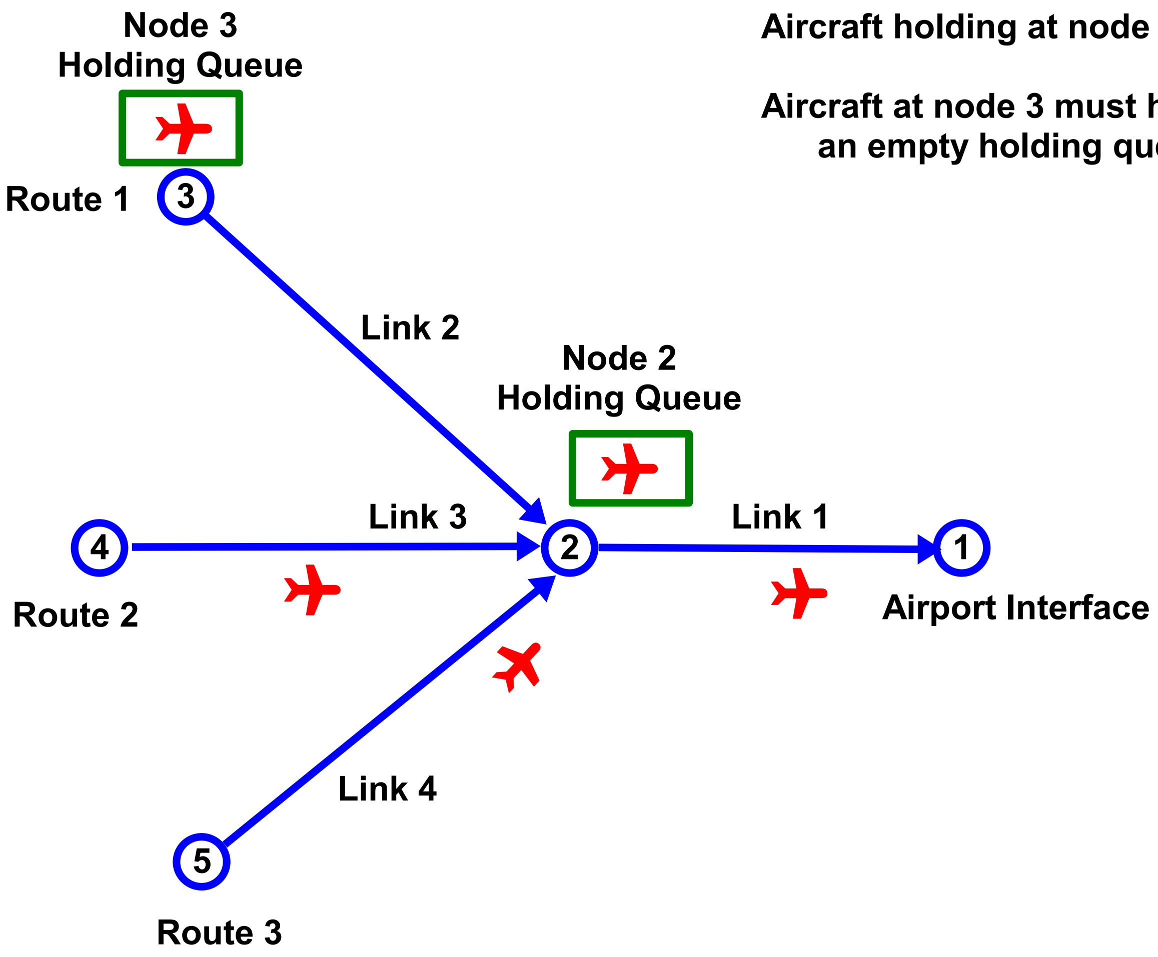
An aircraft holds at current node if:

Strategy 1 - There is an aircraft held at the next node on the route (default).

Strategy 2 - The capacity of the next node's holding queue is full.

Strategy 3 - The holding capacity of the next node is exceeded by the number of aircraft currently holding at that next node plus the number of aircraft approaching it.

Hold Strategy 1



Description:

Aircraft holding at node 2.

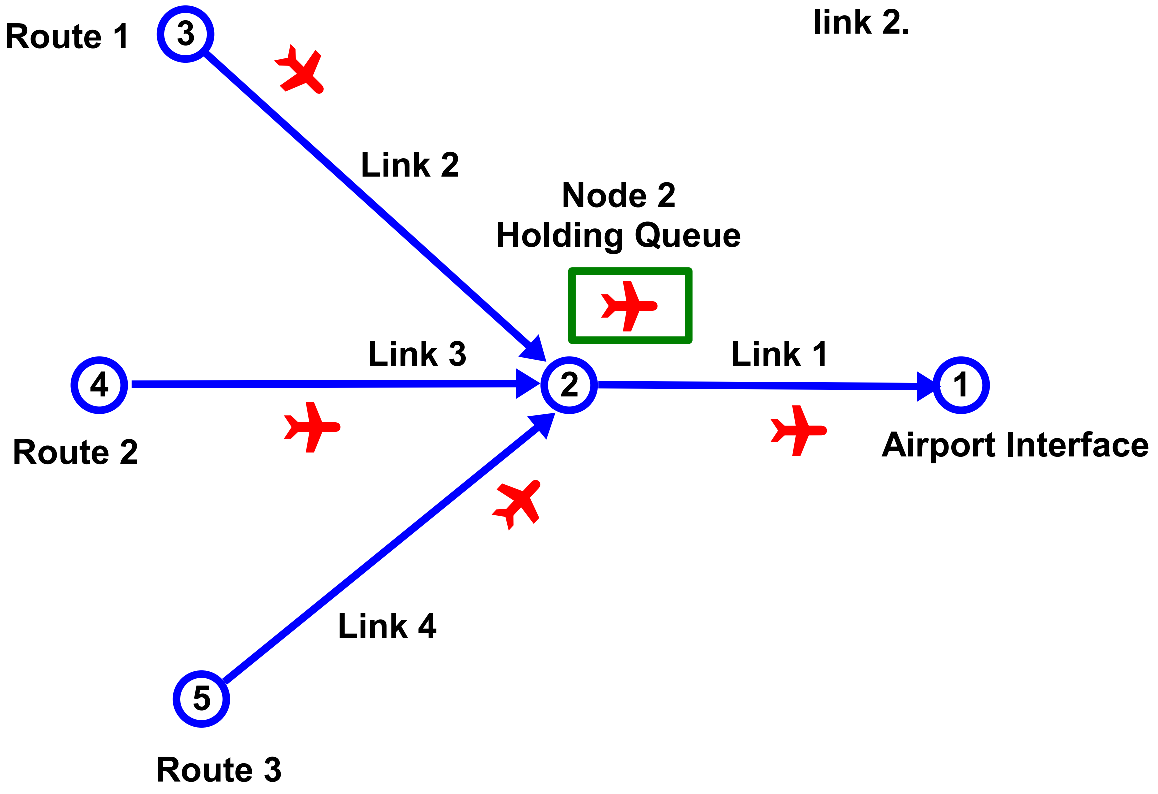
Aircraft at node 3 must hold until node 2 has an empty holding queue.

Hold Strategy 2

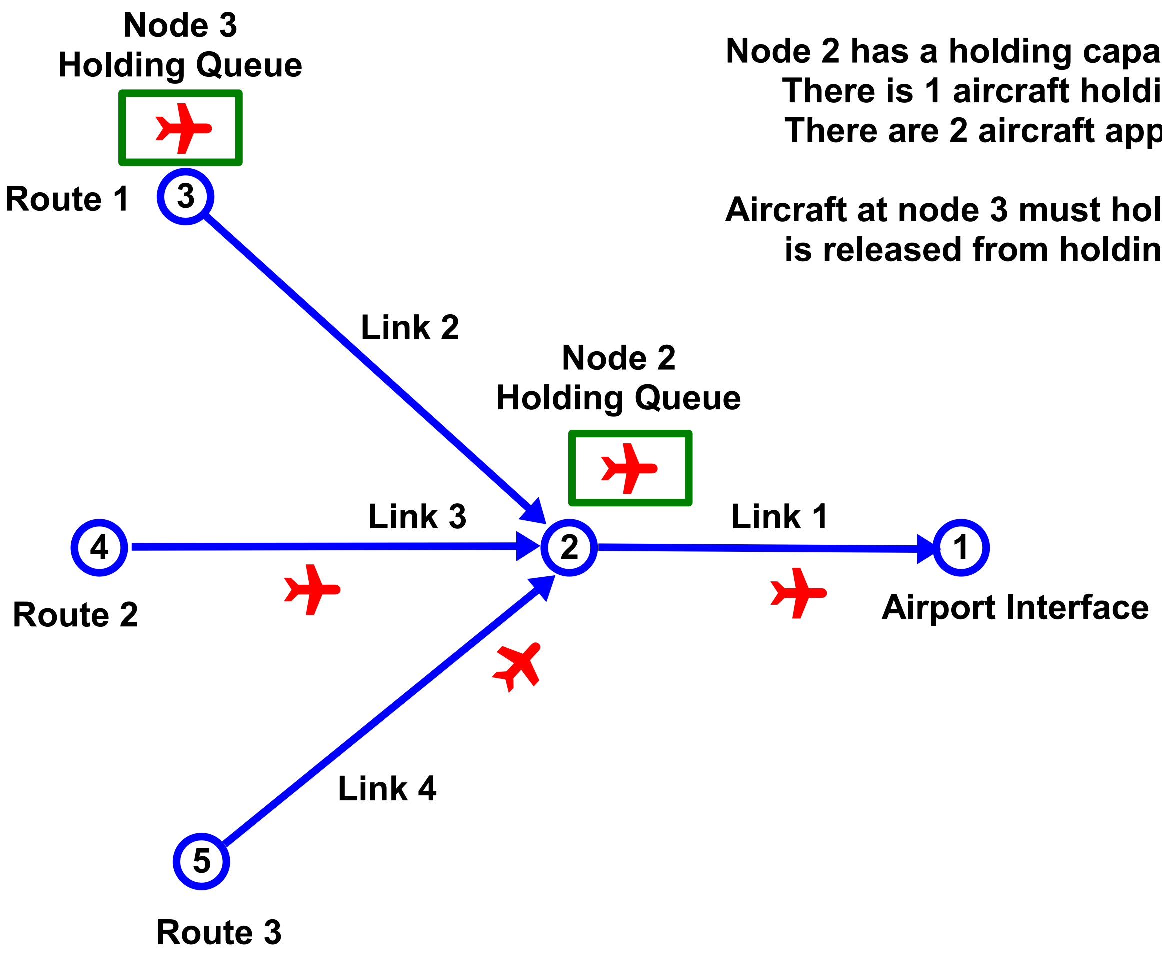
Description:

Node 2 has a holding capacity of 2.
There is 1 aircraft holding in queue.

Aircraft at node 3 is released to proceed on link 2.



Hold Strategy 3



Description:

Node 2 has a holding capacity of 2.
There is 1 aircraft holding in queue.
There are 2 aircraft approaching node 2.

Aircraft at node 3 must hold until aircraft at node 2 is released from holding queue.

Holding Stack Types

Each node has a holding stack type.

- The type is defined by:
  - Minimum holding time in stack.
  - Incremental exit time for release from stack.
  - Holding speed of an aircraft in the stack.

Aircraft Control Strategy

Three levels:

Level I - Aircraft node arrival (there are 3 approaches currently implemented).

Level II - Sequencing control using metering.

Level III - Strategic control using flow control.

Aircraft Node Arrival Strategy

Files an aircraft in a node arrival queue based on the arrival time to the node.

Schedules a node arrival event to be initiated at the arrival time.

Rules for filing aircraft and setting arrival time:

- The strategy is set by data input for the approached node.
- The strategy considers all aircraft approaching a node.
- The strategy uses holding as a last resort.

Node Arrival Strategies Level I Control

QFIFO.

Speed fit.

Multi fit.

In addition, other factors can be incorporated into the above strategies including:

- Avoidance of light/heavy sequencing.
- Denial of aircraft passing on a link.
- Checking sector capacity.

QFIFO - Level I Control

For each aircraft entering a node's arrival queue, QFIFO:

Places the aircraft last in the arrival queue.

Calculates the time it will take to arrive at the node, based on minimum intrail separation from the aircraft before it in the arrival queue.

(Intrail separation is defined to be the greater of:
- **Minimum wake turbulence separation required between the current aircraft and the aircraft ahead of it on the link, or**
- **Node intrail separation set by input data.)**

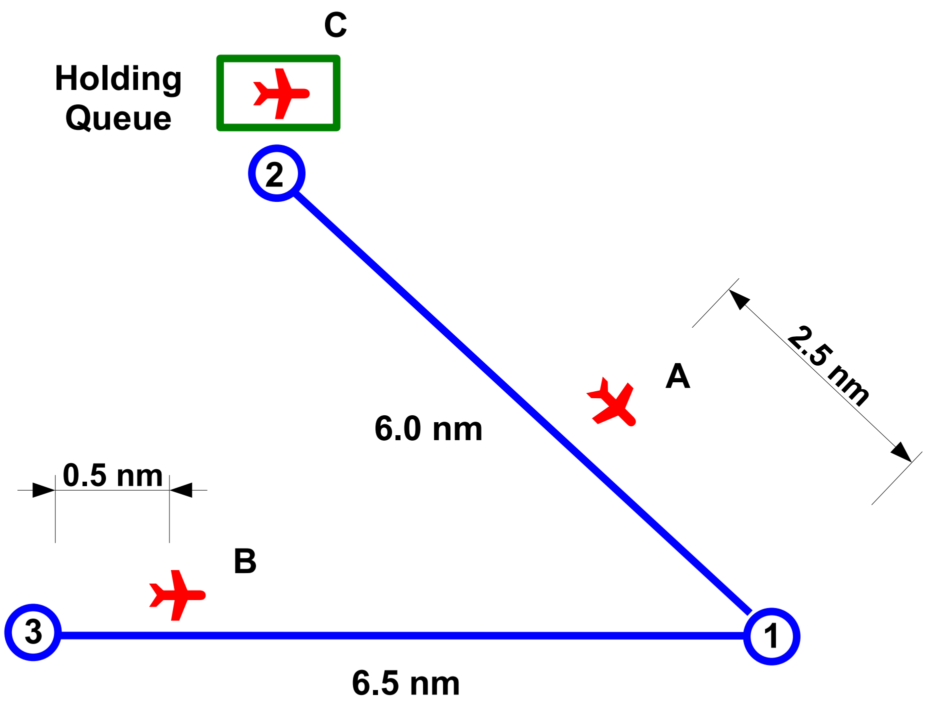
QFIFO - Level I Control (cont.)

Compares the aircraft's link travel time to the time required for it to maintain intrail separation from aircraft preceding it in the node arrival queue.

If the link travel time is less, the aircraft is forced to hold at the current node until intrail separation can be maintained.

QFIFO Logic With Wake Turbulence

Assumptions:
All aircraft are the same type.
Nominal speed = 300 knots,
Wake turbulence for like aircraft Is 3 nmiles.



QFIFO Logic With Wake Turbulence (cont.)

Current time is 1:50:00.

Node arrival queue for node 1 without aircraft C:

Aircraft	TOA	Intrail Separation
A	1:50:30	1:51:06
B	1:51:12	1:51:48

Aircraft C enters queue based on QFIFO strategy.

Projected arrival time at node 1 is 1:51:12.

Aircraft C violates intrail separation with aircraft B, so aircraft C holds 36 seconds at node 2 and then travels 72 seconds with TOA of 1:51:48.

Node arrival queue for node 1 with aircraft C:

Aircraft	TOA	Intrail Separation
A	1:50:30	1:51:06
B	1:51:12	1:51:48
C	1:51:48	

Speed Fit - Level I Control

For an aircraft entering the node arrival queue:

Conditions:

- Position in the arrival queue is based on.the projected time of arrival (TOA) at the node.
- Speed of entering aircraft can be adjusted to change the TOA.

Process:

- Initially the speed is set to nominal speed and the TOA is calculated.
- Based on this TOA, the initial position in the queue is found and checked for:
  - Separation from aircraft preceding.
  - Separation from aircraft succeeding.

Speed Fit - Level I Control (cont.)

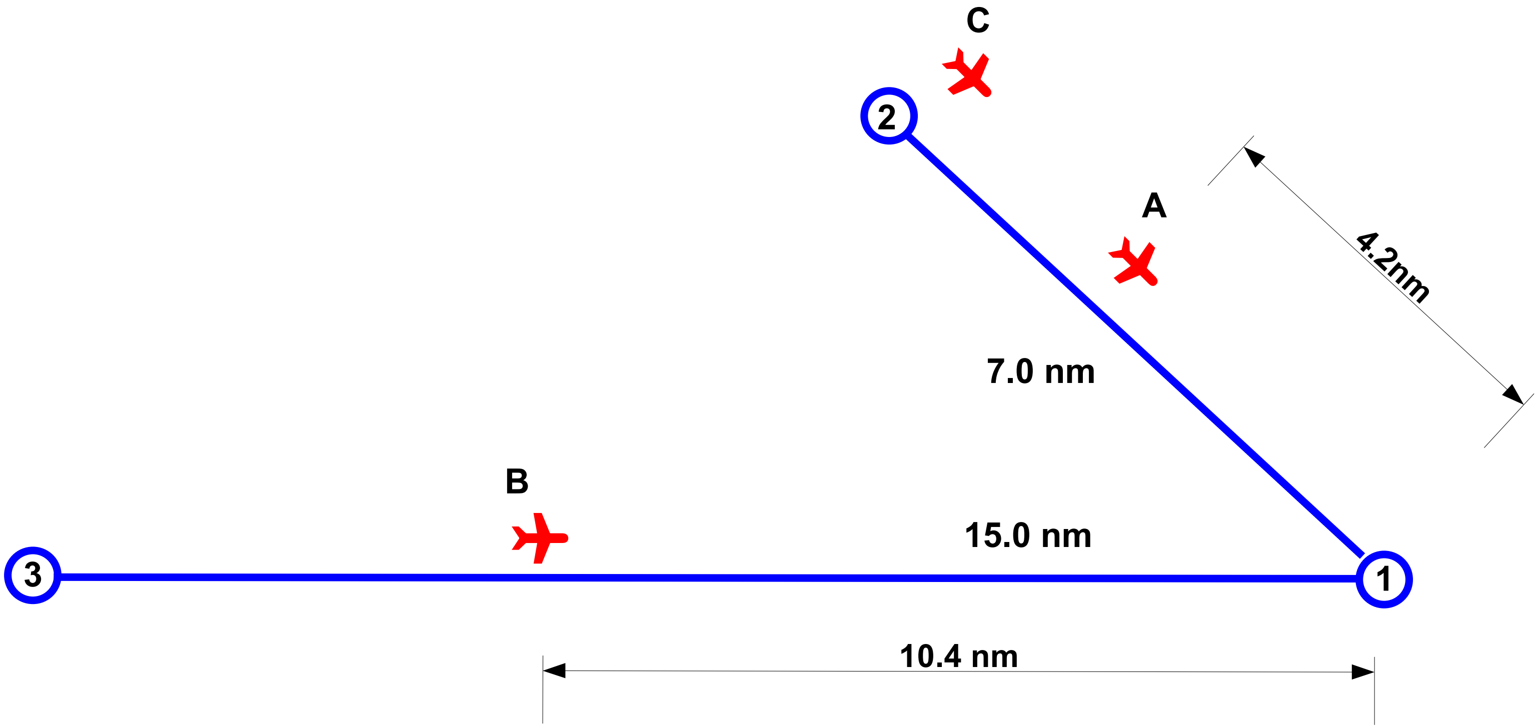
If either separation requirement is violated, the entering aircraft's speed is adjusted in an attempt to make a fit.

If this is not possible, the aircraft is moved up earlier in the node queue in an attempt to find a position with adequate separation between preceding and succeeding aircraft.

If no such niche is found, the aircraft is moved back from the initial position.
At each step there is an attempt to find a position with separation. As a last resort, the aircraft is placed as the final aircraft in the arrival queue with separation from the aircraft preceding it in the queue.

Speed Fit Logic With Wake Turbulence Basic

Assumptions:
All aircraft are the same type.
Minimum speed = 280 knots.
Nomi nal speed = 300 knots. Maximum speed = 320 knots.
Wake turbulence for like aircraft is 3 nmiles.



Speed Fit Logic With Wake Turbulence (cont.)

Current time is 1:50:00.

Node arrival queue for node 1 without aircraft C:

Aircraft	TOA	Speed	Intrail Separation
A	1:50:50	300	1:51:26
B	1:52:05	300	1:52:41

Aircraft C enters queue based on speed fit strategy; its projected TOA based on nominal speed is 1:51:24.

Node arrival queue for node 1 with aircraft C projected:

Aircraft	TOA	Speed	Intrail Separation
A	1:50:50	300	1:51:26
C	1:51:24	300	1:52:00
B	1:52:05	300	1:52:41

This violates 36 second intrail with aircraft A.

Speed Fit Logic With Wake Turbulence (cont.)

Slowing aircraft C to 293 knots yields TOA of 1:51:26. This allows it to maintain intrail separation from aircraft A.

Node arrival queue for node 1 with aircraft C positioned successfully:

Aircraft	TOA	Speed	Intrail Separation
A	1:50:50	300	1:51:26
C	1:51:26	293	1:52:03
B	1:52:05	300	1:52:41

This maintains the intrail separation required between aircraft B and C.

Speed Fit - Level I Control With Position Exchange

Condition:

Speed fit fails at nominal position.

Process:

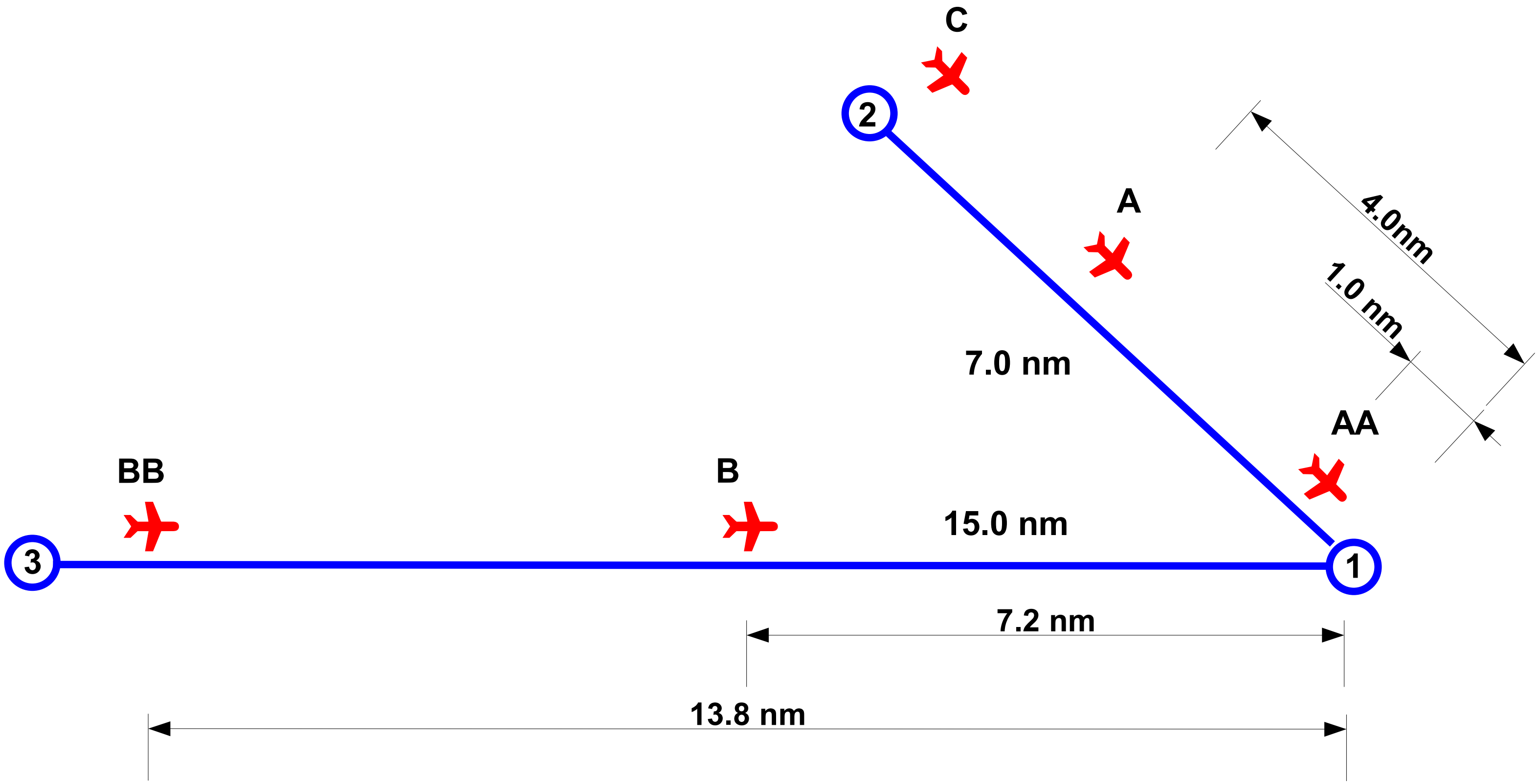
Preceding inter-arrival positions are tried.

Next, succeeding arrival positions are tried.

Worst case, last position in queue.

Speed Fit Logic With Wake Turbulence and Queue Position Change

Assumptions:
All aircraft are the same type.
Minimum speed = 280 knots.
Nominal speed = 300 knots.
Maximum speed = 320 knots.
Wake turbulence for like aircraft is 3 nmiles.



Speed Fit Logic With Wake Turbulence and Queue Position Change (cont.)

Current time is 1:50:00.

Node arrival queue for node 1 without aircraft C:

Aircraft	TOA	Speed	Intrail Separation
AA	1:50:12	300	1:50:48
A	1:50:48	300	1:51:24
B	1:51:26	300	1:52:02
BB	1:52:46	300	1:53:22

Aircraft C enters queue based on speed fit strategy.

Node arrival queue for node 1 with aircraft C projected:

Aircraft	TOA	Speed	Intrail Separation
AA	1:50:12	300	1:50:48
A	1:50:48	300	1:51:24
C	1:51:24	300	1:52:00
B	1:51:26	300	1:52:02
BB	1:52:46	300	1:53:22

Aircraft C has intrail separation with aircraft A, but violates intrail separation requirements with aircraft B.

Speed Fit Logic With Wake Turbulence and Queue Position Change (cont.)

Aircraft C looks for position between AA and A, no separation fit possible.

Second, look to position in front of AA, there is no fit in front of AA.

Next position between Band BB, there is room for separation for C and C will have a TOA of 1:52:02. This requires C to travel at minimum speed for 90 seconds and hold 32 seconds before release.

Node arrival queue for node 1 with aircraft C:

Aircraft	TOA	Speed	Intrail Separation
AA	1:50:12	300	1:50:48
A	1:50:48	300	1:51:24
B	1:51:26	300	1:52:02
C	1:52:02	280	1:52:41
BB	1:52:46	300	1:53:22

Aircraft C has intrail with aircraft B and BB.

Multi Fit - Level I Control

For an aircraft entering node arrival queue.

Conditions:

- Position in the arrival queue is based on the projected time of arrival at the node.
- Speed of the entering aircraft can be adjusted to change the TOA.
- The aircraft preceding and succeeding the entering aircraft at each position in queue can change their speed but not position in queue.

Process:

- Initially the speed is set to nominal speed and TOA is calculated.
- From the TOA the initial position in the queue is found and checked for:
  - Separation from aircraft preceding.
  - Separation from aircraft succeeding.

Multi Fit - Level I Control (cont.)

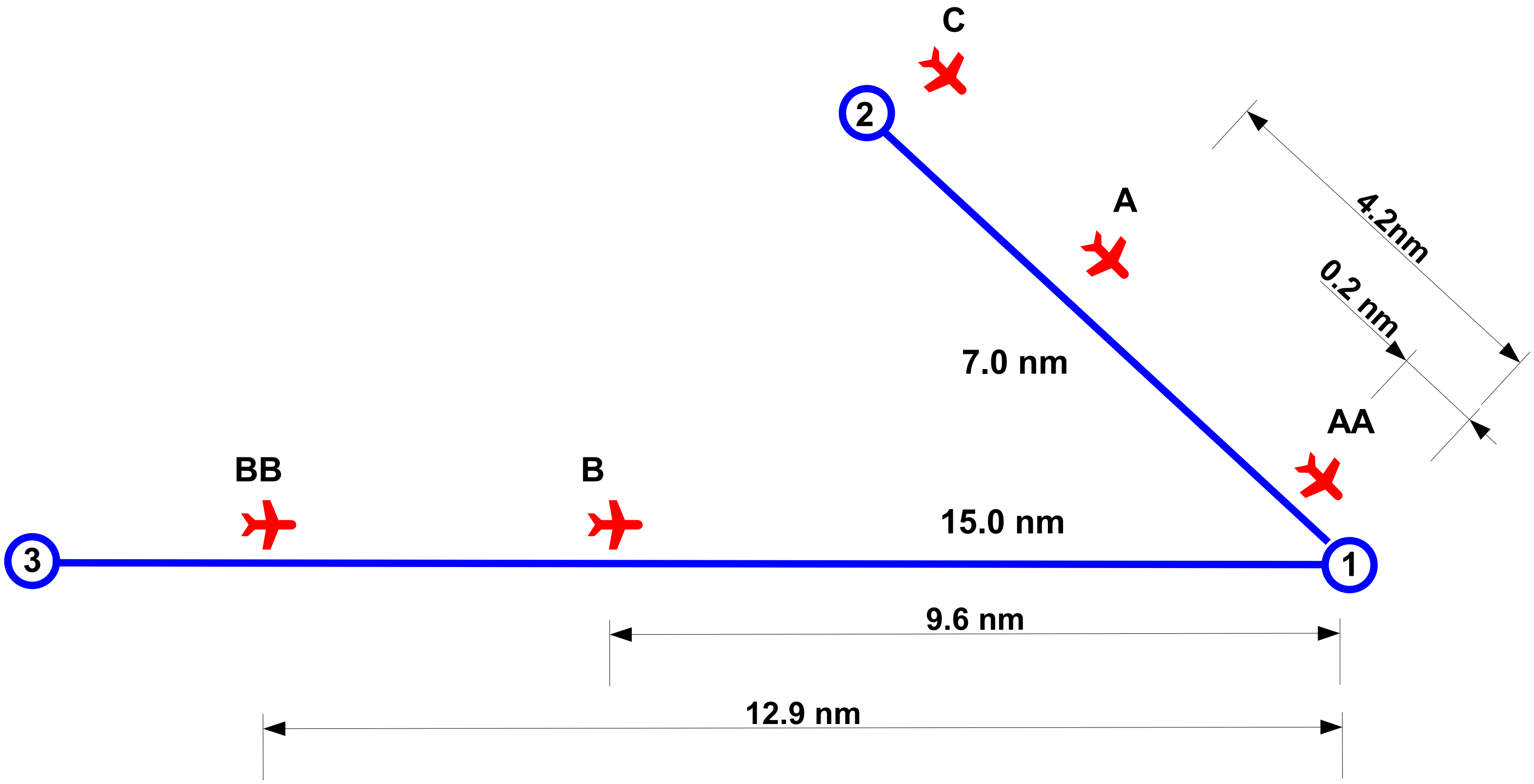
If either separation requirement is violated, the speed of all three aircraft is adjusted to attempt a fit.

If a fit is not possible, the aircraft is moved up earlier in the node queue in an attempt to fit it into each position with separation of both preceding and succeeding aircraft.

If the aircraft cannot be fit into a forward position, its arrival is moved back one position at a time. As a last resort, it becomes the final aircraft in the arrival queue with separation from the aircraft succeeding it in the queue.

Multi Fit Logic With Wake Turbulance

Assumptions:
All aircraft are the same type.
Minimum speed = 280 knots.
Nominal speed = 300 knots. Maximum speed = 320 knots.
Wake turbulence for like aircraft is 3 nmiles.



Multi Fit Logic With Wake Turbulence (cont.)

Current time is 1:50:00.

Node arrival queue for node 1 without aircraft C:

Aircraft	TOA	Speed	Intrail Separation
AA	1:50:02	300	1:50:38
A	1:50:50	300	1:51:26
B	1:51:55	300	1:52:31
BB	1:52:35	300	1:53:11

Aircraft C enters queue based on multi fit strategy; its projected TOA based on nominal speed is 1:51:24.

Node arrival queue for node 1 with aircraft C projected:

Aircraft	TOA	Speed	Intrail Separation
AA	1:50:02	300	1:50:38
A	1:50:50	300	1:51:26
C	1:51:24	300	1:52:00
B	1:51:55	300	1:52:31
BB	1:52:35	300	1:53:11

This violates 36 second intrail separation with both aircraft A and B.

Multi Fit Logic With Wake Turbulence (cont.)

Aircraft C and A's speed are adjusted, but no separation.

Aircraft C and B's speed are adjusted, but no separation.

Next C, A, and B's speeds are adjusted and there is separation.

Node arrival queue for node 1 after multi fit:

Aircraft	TOA	Speed	Intrail Separation
AA	1:50:02	300	1:50:38
A	1:50:47	320	1:51:21
C	1:51:21	311	1:51:56
B	1:51:57	295	1:52:34
BB	1:52:35	300	1:53:11

Miscellaneous – Level I Control

For an aircraft entering the node arrival queue, these additional factors can be incorporated:

Denial of aircraft passing on the link.

Light/Heavy sequencing in the arrival queue.

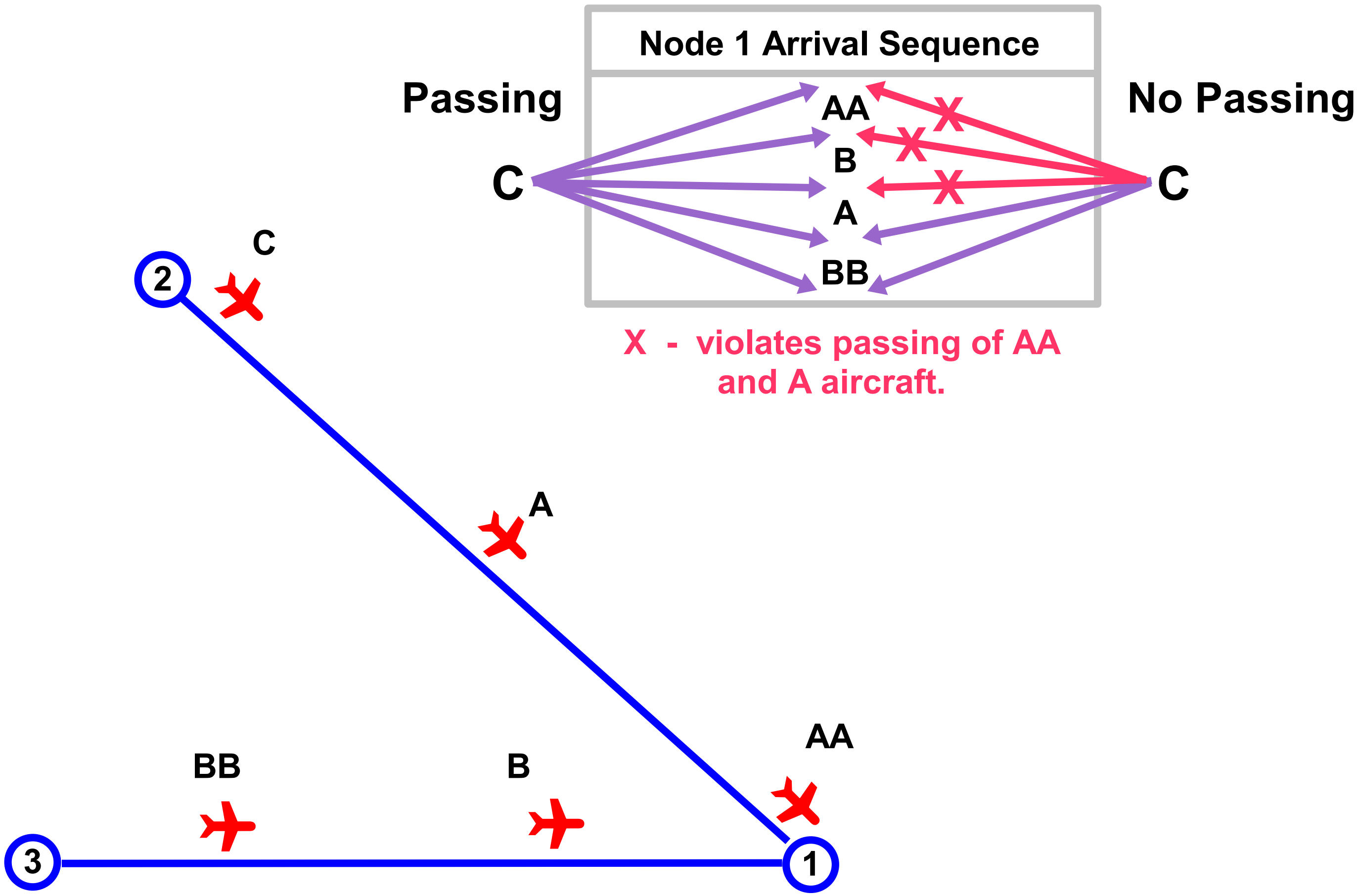
Order of Actions to Impose Delay

Reduce speed based on node strategy.

Vector where wake turbulence on link is not a consideration.

Hold.

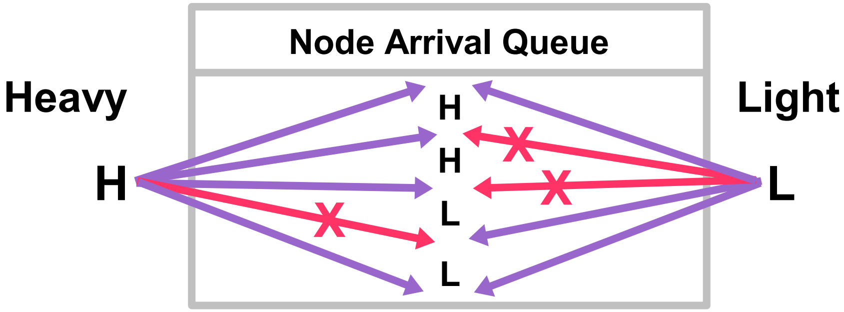
Passing in Node Arrival Queue



X - violates passing of AA and A aircraft.

Light / Heavy Sequencing

Example: A heavy aircraft is entering the queue.



X - violates light/heavy sequencing logic.

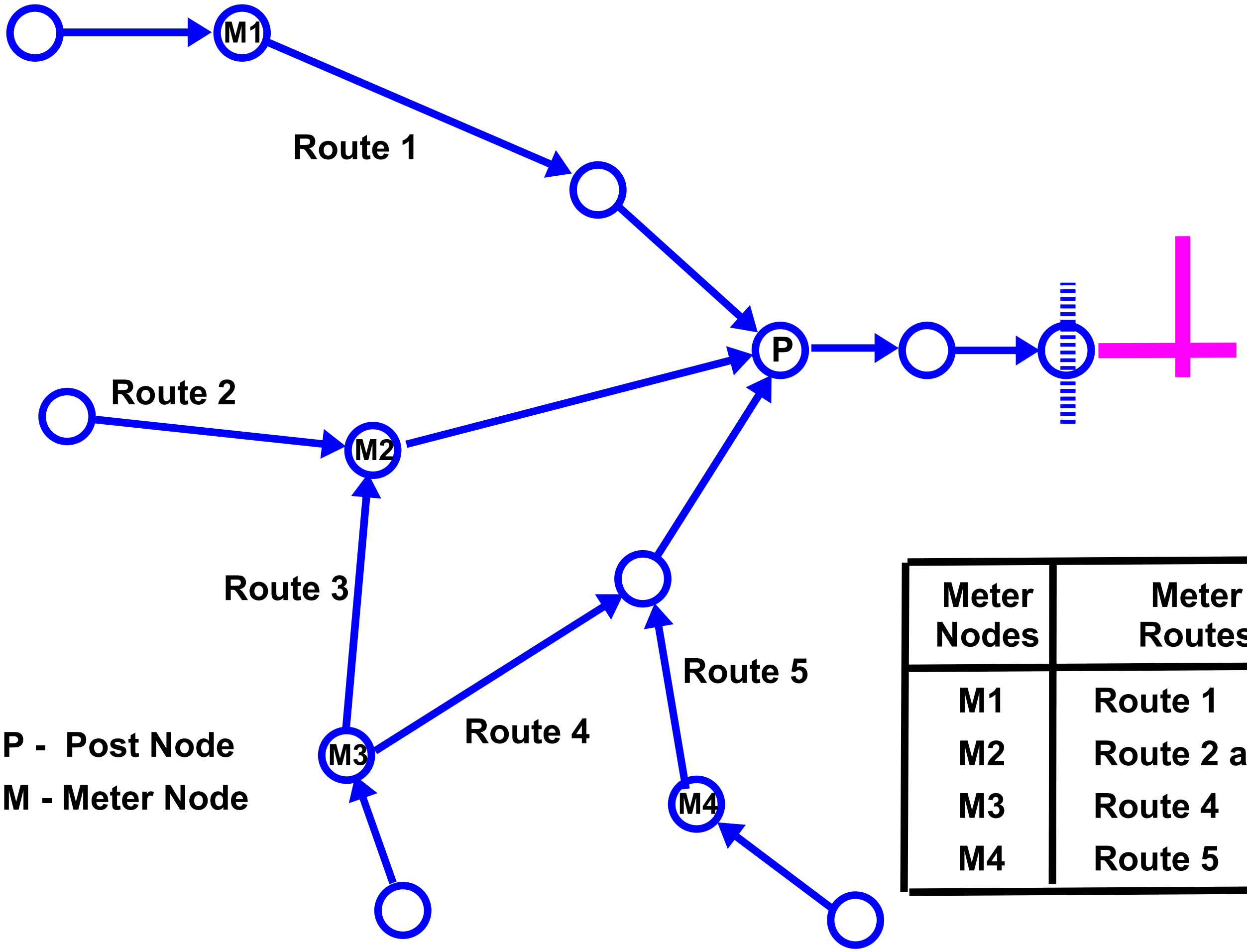
Metering Level II Control

Models the processes by which the controller looks ahead along the route structure network.

Coordinates the movement of individual aircraft in anticipation of specific downstream operational requirements such as merges.

Sequencing is carried out within constraints permitted by level I control, which is operating parallel to level II.

Metered Airspace



P - Post Node

M - Meter Node

Meter Nodes	Meter Routes
M1	Route 1
M2	Route 2 and 3
M3	Route 4
M4	Route 5

Metered Control Process

When an aircraft on a metered route reaches the meter node:

The aircraft is placed in the meter node's arrival queue under level I node arrival strategy.

The aircraft is placed in the post node meter queue based on the position in the meter node's arrival queue plus the nominal time for additional travel to the post node.

Metered Control Process (cont.)

Node arrival strategy control (Level I) is then used to try to resolve conflict at the post node.

This is continued for each node between the meter and post node.

The limitations are:

- The metering control must work within the current node's arrival strategy for conflict resolution.
- No change can be made to the aircraft's position in the current node's arrival queue.
- Only aircraft on designated meter routes are considered.

Terminal Airspace Re-routing

Dynamic terminal area re-routing based on downstream runway congestion.

Aircraft in the terminal area can be re-routed to land at an alternate runway.

The metering control logic is used with restrictions.

Terminal Airspace Re-routing (cont.)

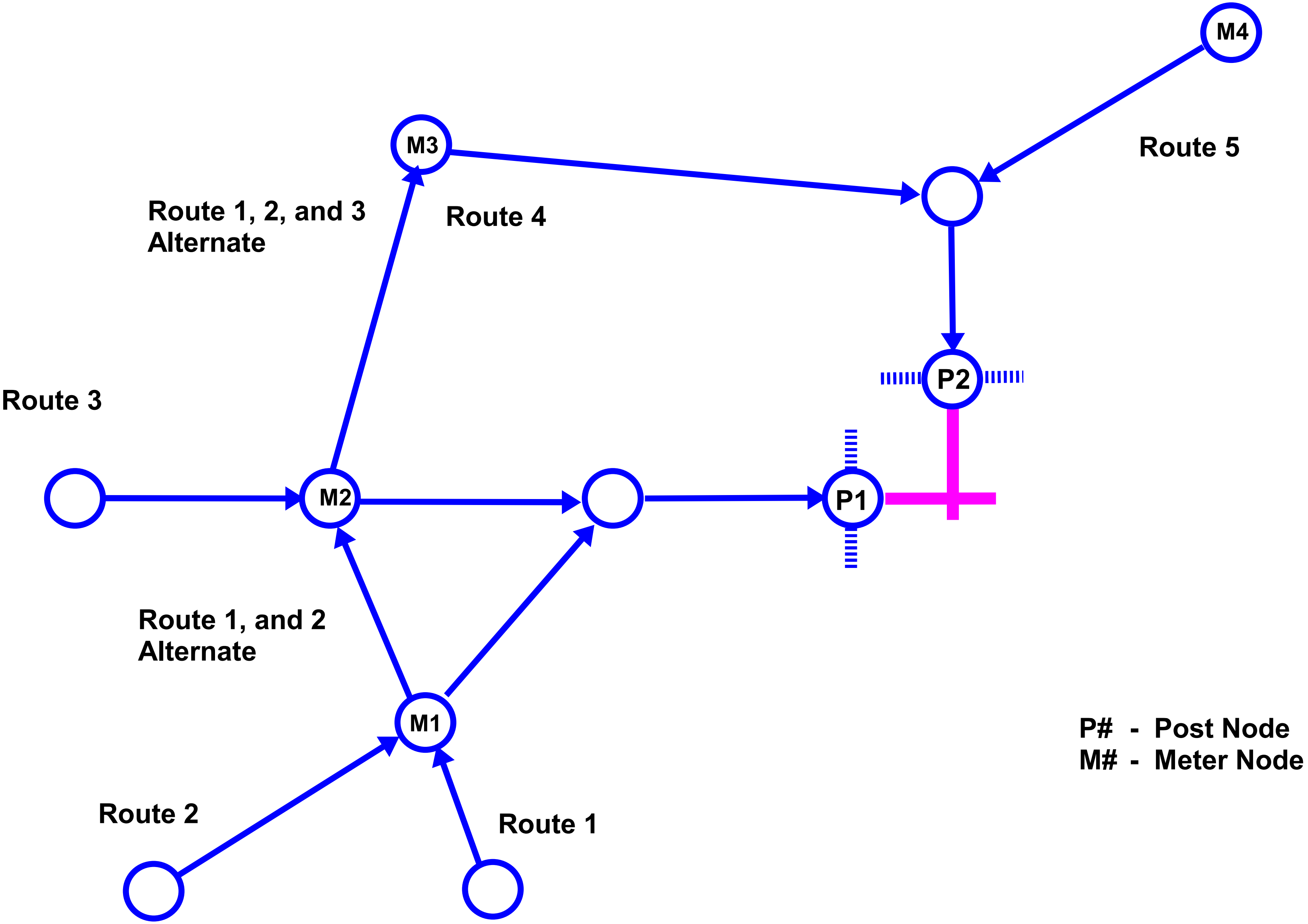
Requirements:

Metering post nodes must be airport interface nodes.

For each such node, two queue length values must be defined:

1. **The number of aircraft in the queue that triggers a search for re-routing to another node.**
2. **The number of aircraft in the queue signaling that re-routing to this node is no longer an option for other nodes.**

Terminal Re-routing Airspace



P# - Post Node
M# - Meter Node

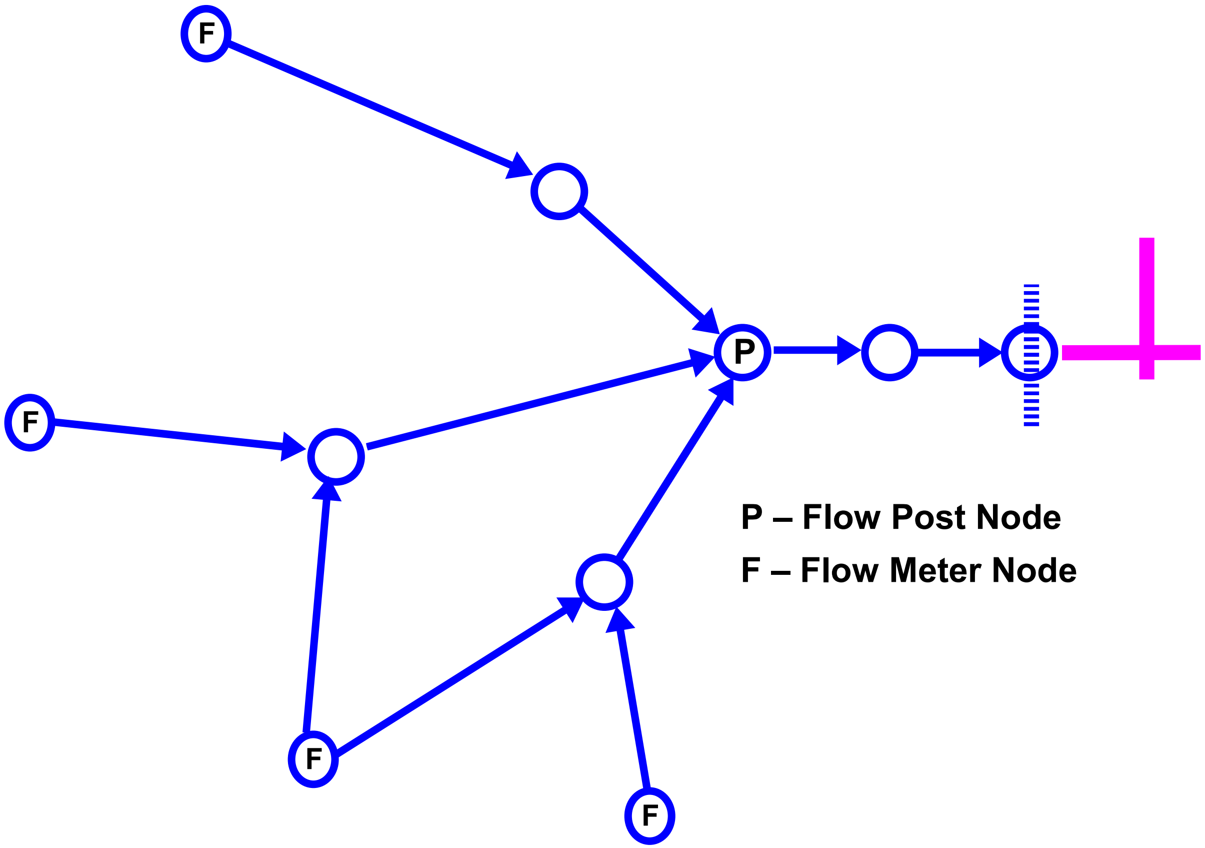
Flow Control
Level III, Control

Simulates the process by which controllers coordinate and implement system-wide procedural rules, and regulate or meter traffic through their airspace.

Determines facility boundary separation rules, allowing traffic to be fed at realistic rates into the sequencing and node arrival environment.

Serves as a traffic modulator, ensuring that aircraft concentrations that would overpower level I and II operations do not occur.

Flow Controlled Airspace



P – Flow Post Node

F – Flow Meter Node

Flow Control Process

Flow control logic is performed at periodic intervals defined by input.

At each flow update, every flow metering node is assigned a flow rate.

The flow rate is based on the following:
- Current projected flow.
- Post node flow rate.

Metering node flow rate is a weighted proportion of the post node.

Flow rate is converted to intrail separation from the metering node.

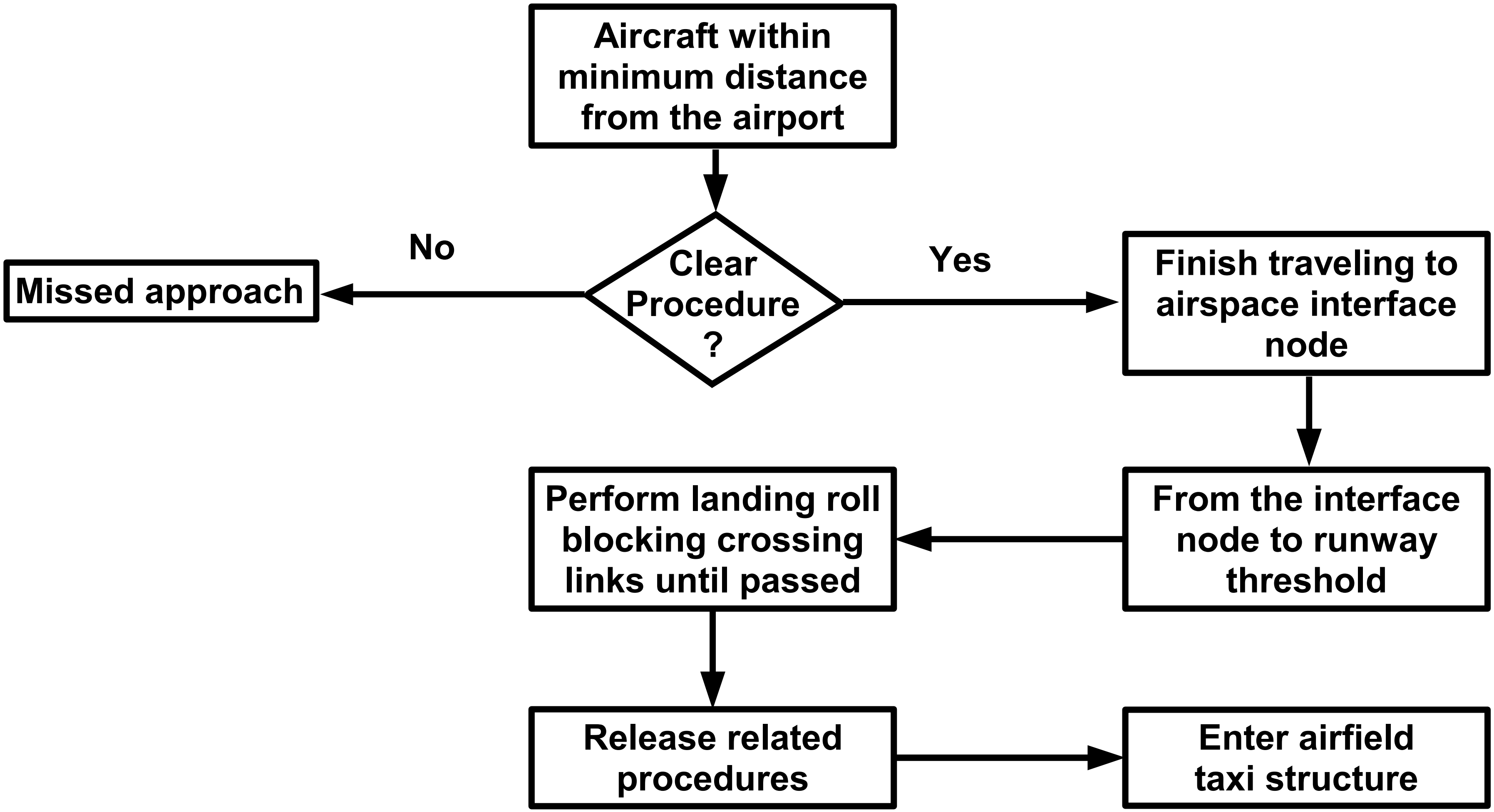
Airport/Airspace Interface Logic

Simulates Air Traffic Control of aircraft executing approach and departure operations.   Uses three subcomponents:

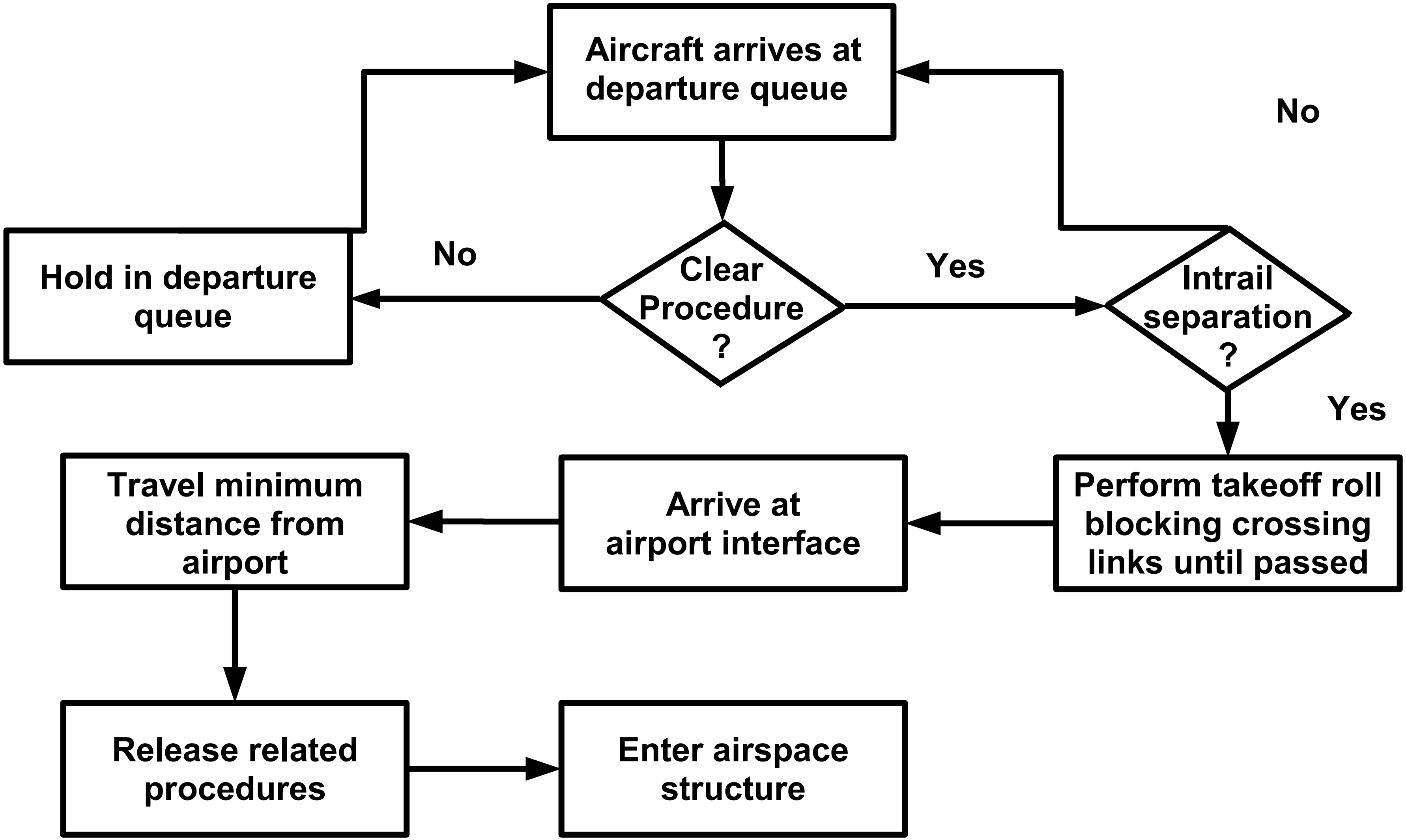
- Final approach control.
- Takeoff/landing control.
- Departure control.

The three subcomponents are interactively linked to ensure that all aspects of airport/airspace movement are properly integrated.

Aircraft Landing



Aircraft Takeoff



Final Approach Control

Simulates the processes by which controllers set-up, monitor and adjust the spacing of aircraft along the final approach to a runway system.

The runway system can include single or complex runway structures, e.g., closely-spaced parallels or intersecting runways.

Final approach logic also ensures that landing runway operating rules are not violated by monitoring runway occupancy times and runway crossing nodes.

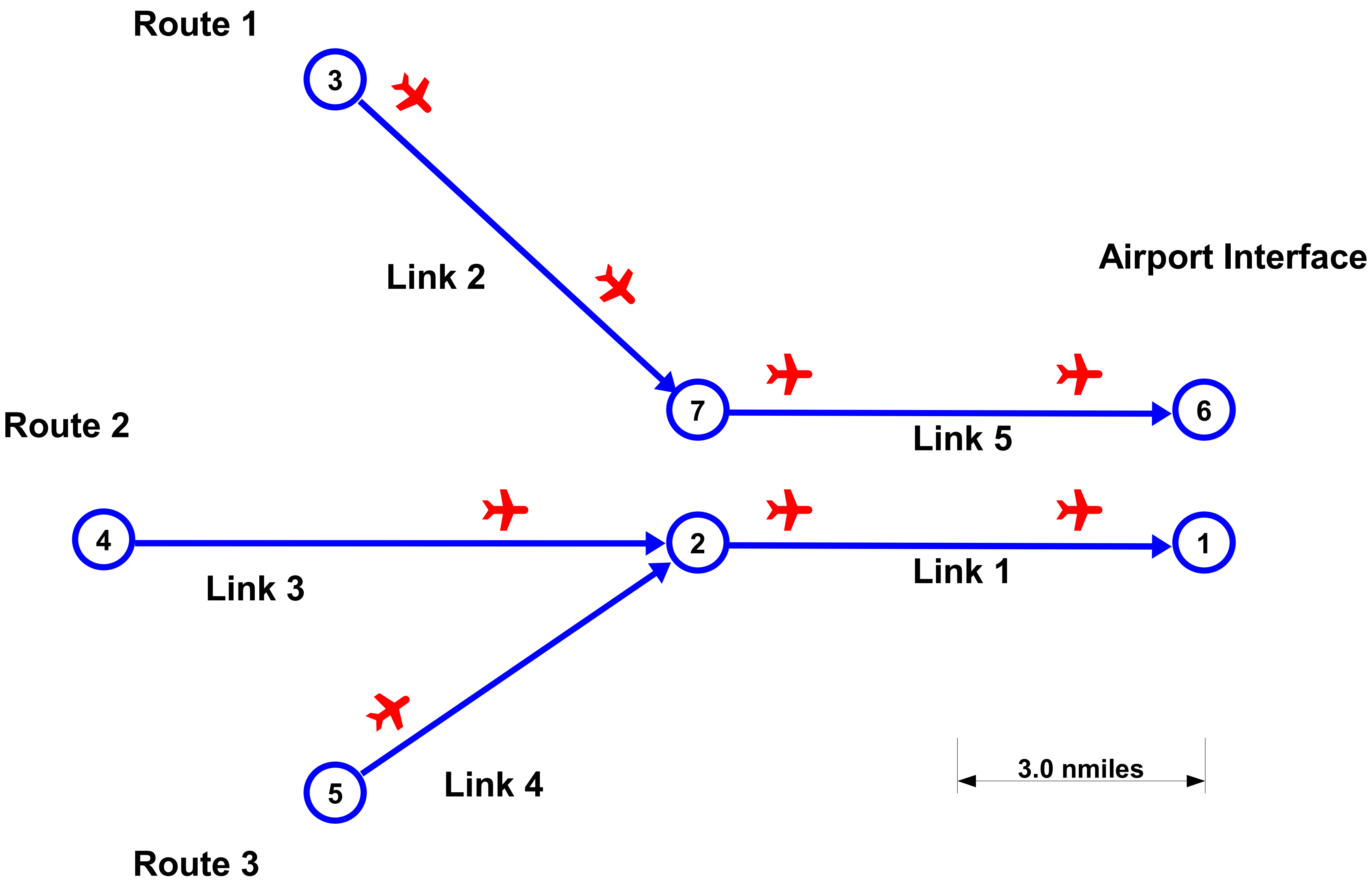
Pairwise Operation

Two aircraft may approach in a side-by configuration as long as adequate separation is maintained between the preceding and following aircraft.

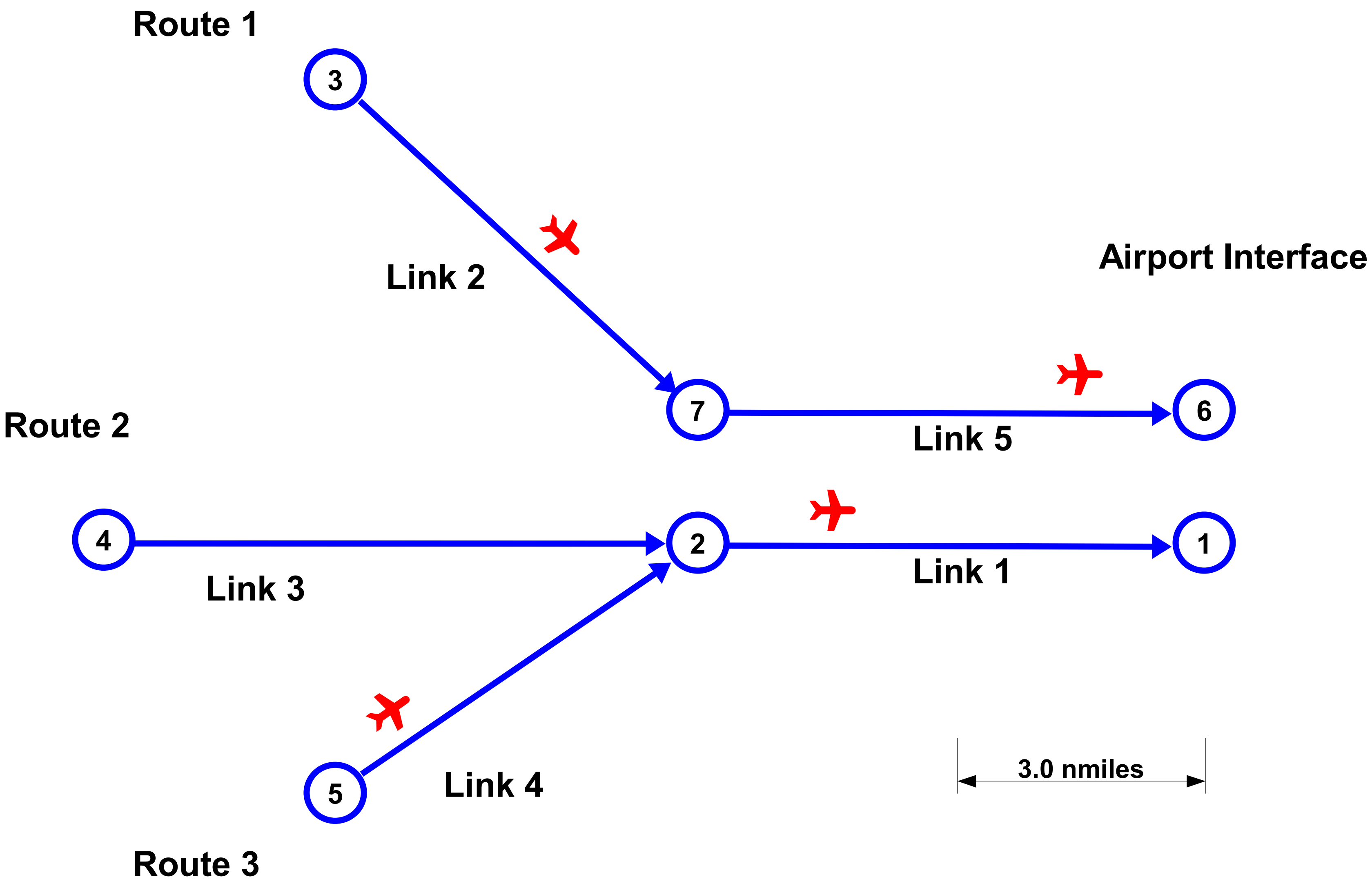
Requires links to be mated as described inlink input.

Uses Level I airspace logic to set up aircraft for pairwise coupling as they converge on final approach.

Final Approach Control 1



Final Approach Control 2



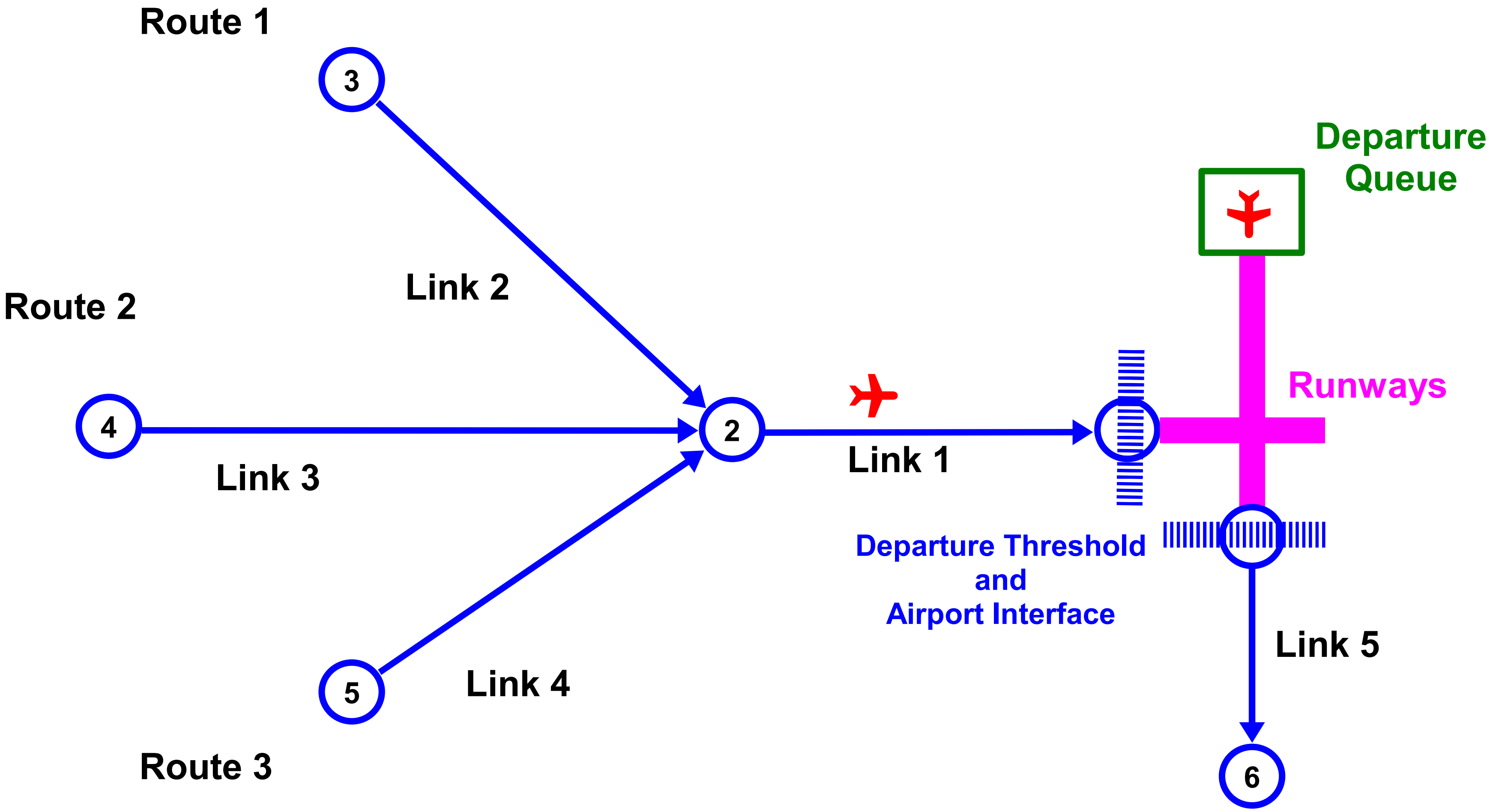
Takeoff/Landing Control

Runway configuration requires a high degree of coordination between takeoffs and landings to maximize runway utilization.

Typically, takeoffs and landings are interleaved with each subject to the separation constraints.

The specific logic for the interaction is defined by the procedure data.

Takeoff/Landing Control



Departure Control

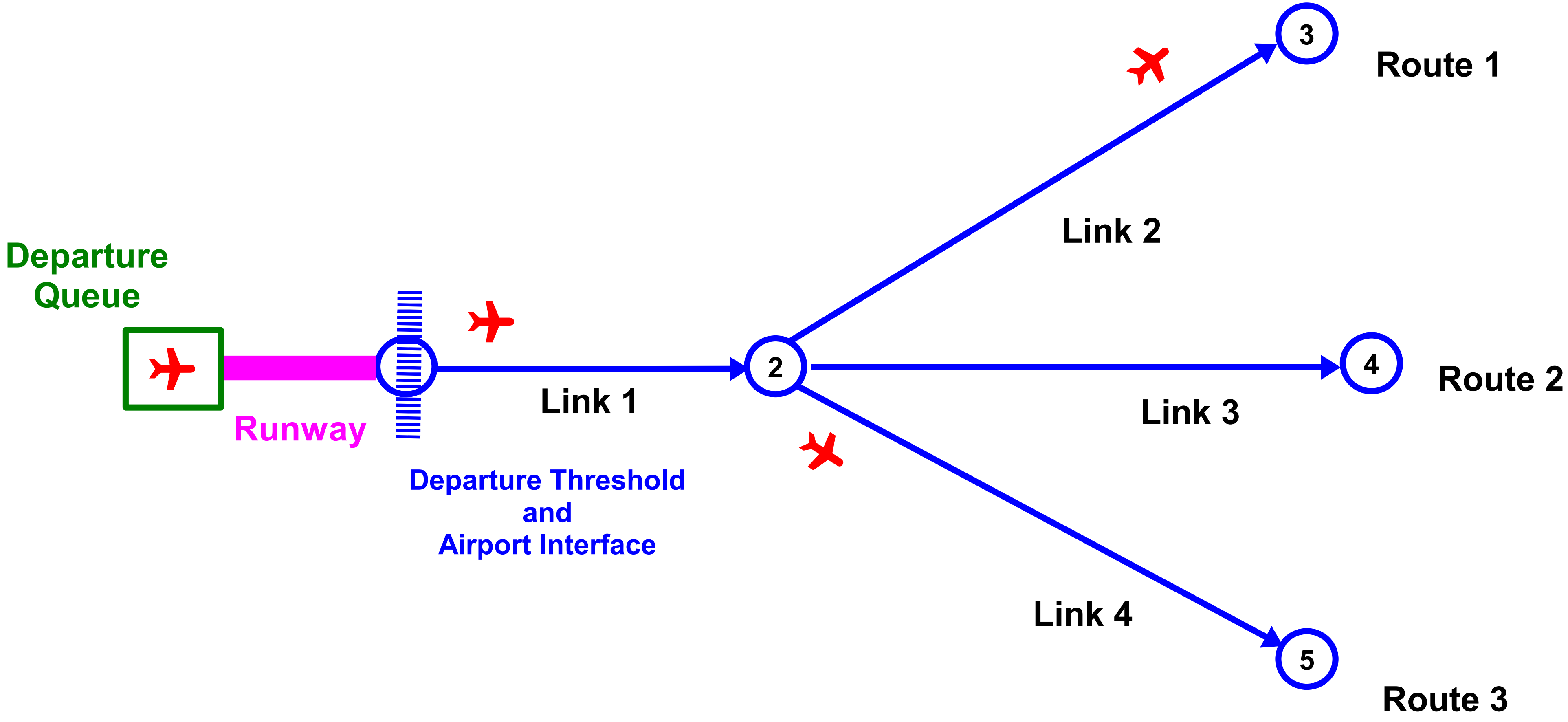
Controls include:

Separation requirement for successive departures.

Spacing rules which vary by type of aircraft and according to whether successive aircraft are diverging or following each other.

The rules are set by the procedure data input.

Departure Control



Procedures

Define the interface of airspace routes and airfield runways.

The interface node is represented on the airspace route as a node. On the ground it is the departure threshold.

A procedure defines:

- The minimum distance from the airport at which each related procedure is blocked.
- The runway occupancy time for the aircraft on the ground during which related procedures are blocked.

Related Procedures

Procedures are grouped as related procedures based on their interactions.

- For example, one aircraft may block a second aircraft when the first aircraft's distance from the airport prevents the second aircraft from safely executing its procedures.

- Two procedures can have different restrictions for the same related procedure.

Airfield Logic

Airfield network:

- The structure within which the simulation works to move aircraft on ground.
- The airfield network can have multiple airports defined, each with its own characteristics.

Aircraft movement on ground:

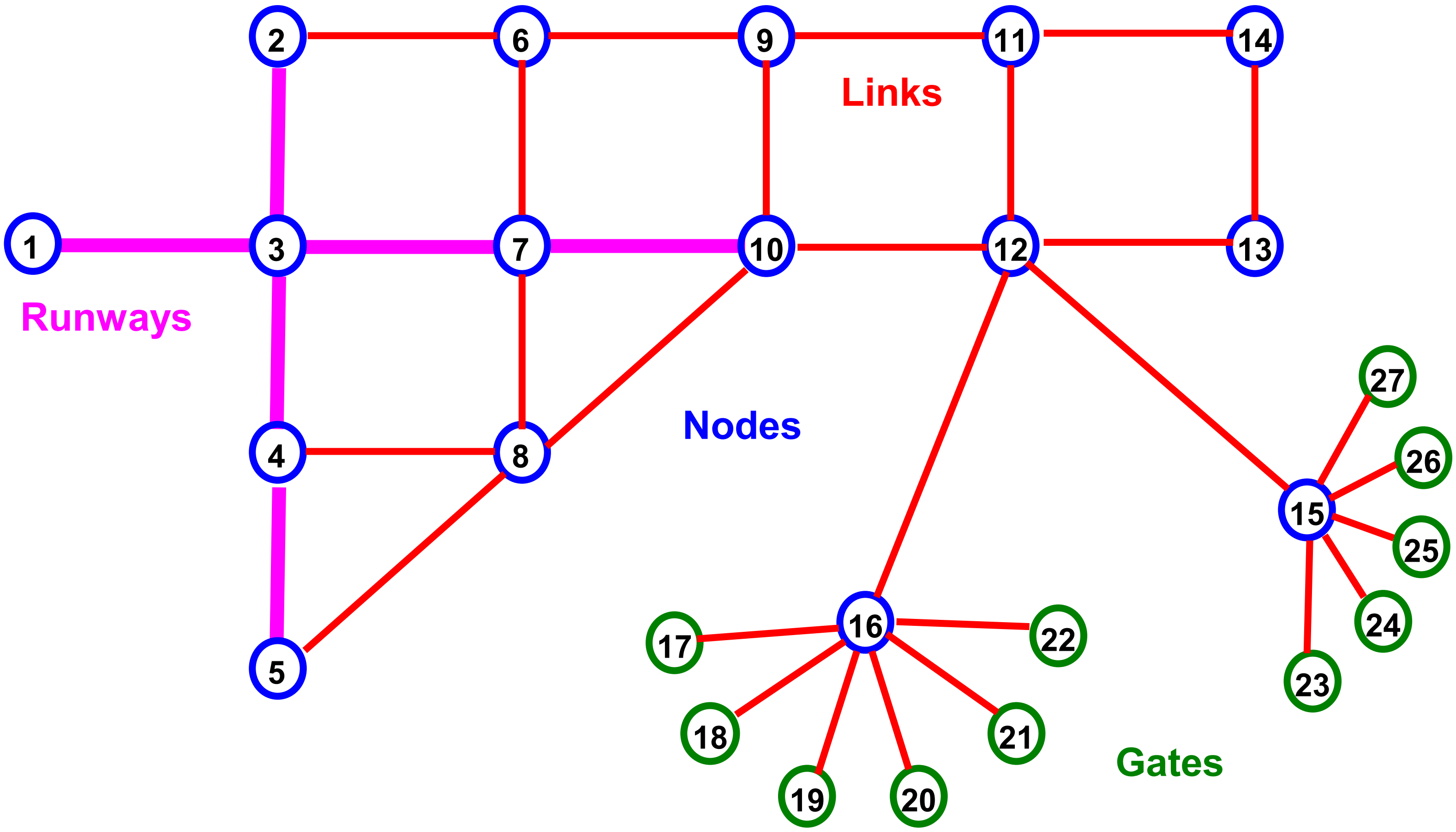
- Basic movement on taxipaths.
- Holding.
- Runway management.

Airfield Network

Consists of:

- Gates for loading/unloading.
- Taxipaths for aircraft movement between gates and runways.
- Runways for takeoffs and landings.

Airfield Network (cont)



Airfield Nodes

Points at an airport where intersections occur.

Nodes can be of several different types:

- Gates.
- Runway nodes.
- Departure queues.

Airfield Node Process

All airfield logic is performed at the airfield nodes by clearing an aircraft from one link to the next using three queues:

- Link transit queue.
- Link holding queue.
- Link entry queue.

Airfield Links

Airfield finks connect two airfield nodes.

All aircraft movement and holding is done on links with the exception of gate holds and departure queue holding.

Links can be:

Runway links.

Taxiway links.

Links crossing runways.

Links connecting to gates.

Runway Operations

The runway is defined by a series of airfield links.

An aircraft roll-distance on a runway is determined by a random draw from a cumulative distribution. This distribution varies by whether the roll is for takeoff or landing and by the aircraft's type.

Examples of cumulative distribution input:

Feet	Prob.	Feet	Prob.	Feet	Prob.
1000	0.0			8000	1.0
1000	0.0	6000	0.50	8000	1.0

(random linear function)

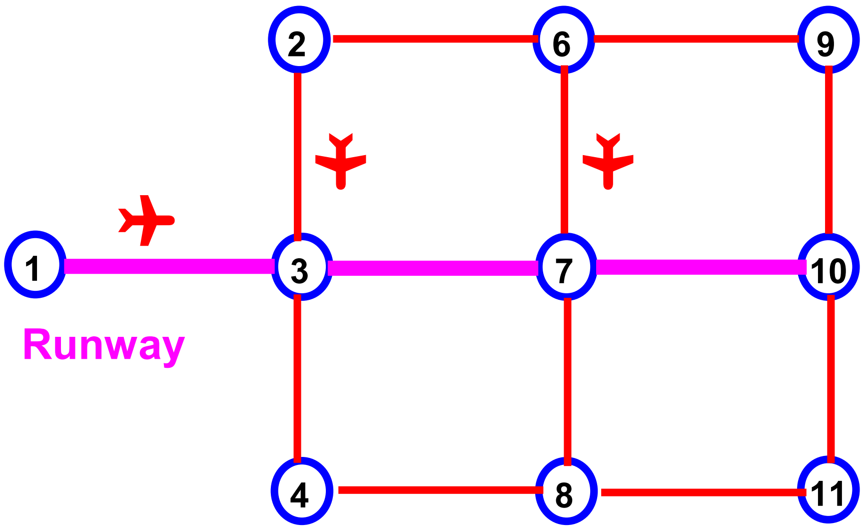
Runway Operations (cont)

After completion of a take-off roll, the aircraft transitions to the airspace interface node where the airspace logic will take over.

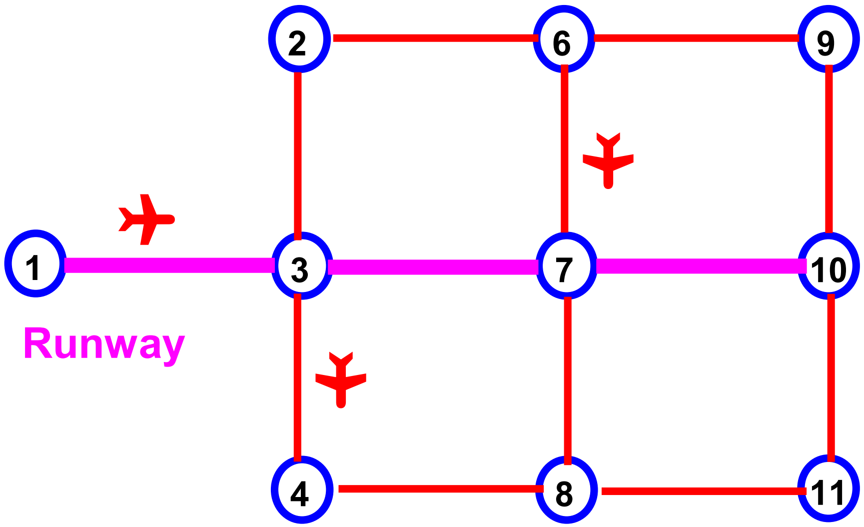
After completion of a landing roll, the aircraft performs a high speed taxi to a runway exit determined by the aircraft's assigned taxipath.

Runway and Taxipath Interaction

Both aircraft are blocked



One aircraft is unblocked



Airfield Movement

Rules

All movement is on links.

An aircraft must maintain separation from the aircraft preceeding it on a link.

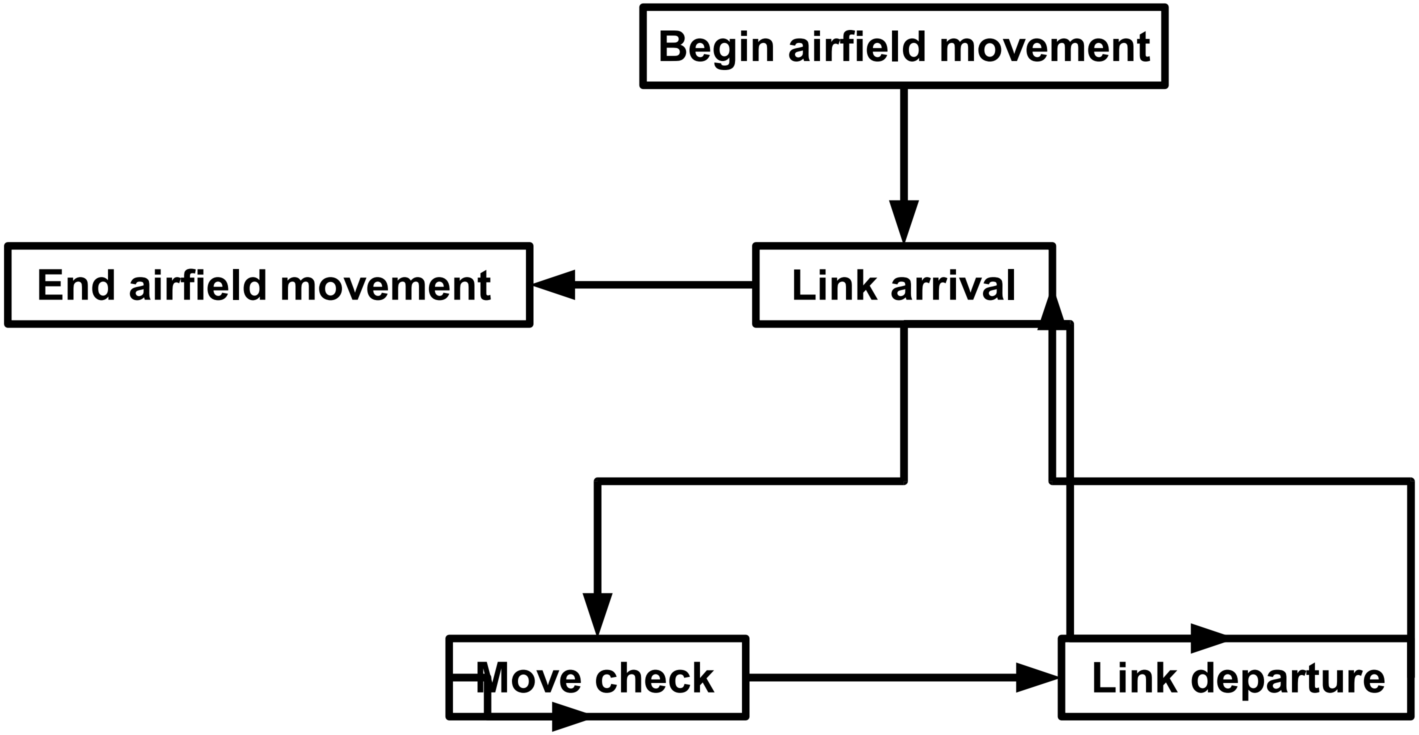
All aircraft must taxi at the taxi speed.

Runway travel is at takeoff roll speed, landing roll speed, or runway taxi speed.

Passing of aircraft is an option for each link.

All holding is done on links.

Airfield Movement



Begin airfield movement

End airfield movement

Link arrival

Move check

Link departure

Taxipath Logic

Taxipaths are determined by optimization, or by input, or by a combination of these two.

The user can specify the taxipath between a gate and a runway.

The user can let SIMMOD find the taxipath based on minimal transit time including the holding times based on projected taxi-link congestion.

The user can specify the first portion of the taxipath and let SIMMOD optimize the rest.

(More under events)

Taxipath Optimization

Links are checked to determine if they are feasible choices based on:

- Direction of link.
- Type of flights allowed on link (arrivals or departures).
- Size constraint for aircraft on the link.

Taxipath Operations

After a taxipath has been determined for an aircraft, a reservation notice is made for the aircraft at each node in the taxipath. The notice contains:

- Time of arrival at a node.
- The node's identifying number.
- The link to take leaving the node.

Aircraft Holding

Always done on a link.

Required:

- If there is no passing and a preceding aircraft is being held on the link.
- If the link capacity for the next link is filled.
- If the separation between this aircraft and its predecessor would be less ,than required.
- If the link has unidirectional flow and it's currently set in the opposite direction.

Gate Definition

Gates have size restrictions.

Gates can have a list of links to the edge of the apron area (avoids optimization time for taxipaths in the apron area).

A single gate node can be used to represent several gates to simplify the modeling of an airfield by giving it a capacity greater than 1.

Gate Logic

Aircraft experience loading and unloading times at the gates to model gate occupancy.

Aircraft leave the simulation after gatewaits (arrivals).

Aircraft begin airfield movement after gatewaits (departures).

Gate blocking (consideration of wide bodies and adjacent gates).

Push backs and apron queueing are also accounted for.

Airlines and Gates

Airlines own gates.

The user can:

Specify a gate for an aircraft.

Choose to let SIMMOD select from the airline's available gates.

Choose a gate and specify that SIMMOD choose an alternate if that gate is filled.

Gate ownership can be determined by a list of authorized airlines, or the gate can be declared available to all airlines.

Departure Queues

Occur at last node of the taxiway structure between a gate and a runway

Queue control may be FIFO, or the departure sequence can be determined by procedure availability (for example, alternating between east and west destinations).

Bank Logic

Defines an airline's interconnection between flights for hubbing.

Hubbing requires all aircraft within a bank to be at their gates simultaneously for a given amount of time to allow passengers to make connections.

Using banks affect departure dependability, taxi-out times, and congestion in the terminal airspace.

Bank Process

Example:

Bank of aircraft land within 20 minutes.

Remain on the ground for 30 minutes to allow passengers to change planes.

Bank of aircraft departs.

Decision:

If one of the aircraft is late in landing. . .

What impact does the late aircraft have on other aircraft?

How long should other aircraft hold?

Event Types

Aircraft Events.

Network Adjustments.

Simulation Control.

Aircraft Events

Arrivals.

Emplane - departures.

Multi - arrivals.

Multi - departures.

Arrivals

Three Types:

- **Basic arrivals to a modeled airfield.**
- **Arrivals to a modeled airfield with scheduled redepartures.**
- **Arrivals at a terminal airspace node without a modeled airfield (overflights).**

Arrival Definition

Scheduled arrival time.

Aircraft identification.

Lateness probability distribution.

Taxipath and gate specification.

Route specification.

Departure

Two types:

> **Basic departure - aircraft leaves airspace without landing.**
>
> **Departures which will land at a modeled airfield.**

Emplane - Departures

Scheduled departure time.

Aircraft identification.

Lateness probability distribution.

Taxipath and gate specification.

Route specification.

Multi – Arrivals

Similar to an arrival except:

Several aircraft arrivals are generated randomly over a specified time interval.

No provision for turnaround.

Automatically generated flight numbers: MA_#

Multi - Departures

Similar to a departure except:

- Several departures are generated randomly over a specified time interval.
- Automatically generated flight numbers: MD_#

Modeling Considerations

To model an existing schedule, use arrivals and emplanements.

For a statistical study of capacities or the generation of a stochastic background, use multi - arrivals and multi - departures.

Cloning

Generates increase traffic based on existing schedule by:

Defining a probability for increasing existing traffic by route.

Using Setclone.

Network Adjustments

Set Node, Links, and Sectors.

Set Meter nodes and Routes.

Set Plan.

Set Injection and Procedures.

Set Runway Crossing Times.

Set Weather and Wind.

Set Nodes, Links, and Sectors

Reset parameters using:

- Setnode - for intrail distance, strategy, and holding characteristics.

- Setlink - for length, heading, overtake flag, wake turbulence, capacity, and delay absorbed.

- Setsect - for capacity.

Set Meter Nodes and Routes

Reset intrail separation using:

- **Setroute - for all nodes on the route and for each plan.**
- **Setmeter - for a post node.**

Setplan

During the simulation we can specify at most an exchange of one set of routes for another set.

The exchange is specified route by route.

Transition rules for aircraft can be specified as follows:

All new arrival aircraft use new routes.

New departures can be held until full transition. This is determined by procedure logic.

Existing traffic may:

Continue on an old route until end of flight

or Transition to the new route using transition logic

or Use a combination of these options where choice is determined by the aircraft's position on the route.

Set Injections and Procedures

Inhibits or uninhibits using:

- **Setinj - for arrivals to the airspace by injection.**
- **Setproc - for arrival and departure procedures.**

Set Runway Crossing Times

Sets:

Setxng - the runway crossing priority based on the number of aircraft waiting to cross and the amount of time each aircraft is required to wait.

Set Wind and Weather

Sets:

- **Setwx - adjust operating ceiling and/or runway visual range to allow or preclude landings and departures based on aircraft type.**

- **Setwind - affects the true speed of aircraft on links.**

Wind Calculation

Variables:

- Wind speed.
- Wind heading.
- Aircraft speed.
- Average link heading.

Headwind = cos (Wind heading – Average link heading) * Wind speed

$$\text{Crab factor} = 1 - \frac{\text{Wind speed}^{2} - \text{Head wind}^{2}}{\text{Aircraft Speed}^{2}}$$

New Aircraft Speed = Aircraft Speed * Crab factor - Headwind

Missed Approach

Occurs when ceiling or runway visual range is insufficient or runway procedure is blocked.

Logic:

Go around and try again.

Land at another airport.

Exit airspace via another path.

Exit system at the interface node (default).

Simulation Control

Control.

End Simulation.

End Seed.

Periodic Reports.

Trace.

End Simulation

Schedules an end of simulation time.

Activates report generation.

Does not clear any remaining traffic from queues.

Control

Found in the RUNDATA file.

Sets up the number of replications.

Assigns the random number streams.

Assigns the starting iteration number.

End Seed

Resets the statistical data accumulation.

Can specify whether a report of statistical values at reset time is to be printed and the run iteration(s) for which such a report to be printed.

Used so that statistics only reflect "steady state", i.e., normal operations.

Periodic Reports

Used to start the printing of statistical data at a fixed time and thereafter at specified time intervals.

Can also be used to stop previously set periodic printing.

Trace

Controls the contents of:

- **Simulation log.**
- **Final reports.**
- **Post-processing files.**

Simulation Log

Found in the SIMU04 file.

A report detailing each action performed by an aircraft during the simulation. Useful in identifying problems with simulation data.

Activated using the TRACE command.

These messages are optional. One can choose messages for groups of actions or messages for individual actions.

Can specify the time period for which the messages are to be printed. Should be approached carefully given the potential volume of messages.

Final Reports and Post-processing Files

Specifies the time period during which data is gathered for the final report files and the post-processor files.

The simulation post-processor files are used in the fuelburn post-processor, the animation, the statistical graphs, and the report generator.

Modeling Strategies

1. Define the field of study.

2. Choose to use only those SIMMOD features needed to meet the study's requirements. Consider the following choices:

    a) Actual schedule vs. stochastic generation.

    b) Full airspace vs. interface node.

    c) Full airfield vs. runways with a gate sink.

    d) All runways vs. a pair of crossing runways.

Modeling Strategies (cont.)

3. Suggested data sources:

- Radar tapes are used to:

    1) Calibrate the model.
    2) Define the airspace.
    3) Create arrival and departure events.

- OAG - used to create arrival and departure events.

- Aeronautical Charts

    - Instrument approach procedure charts.
    - Enroute low and high altitude charts.
    - Sectional and VFR terminal area charts - used to define airspace and procedures.
    - Obstruction charts. used to define the airfield.

Modeling Strategies (cont.)

4.) Data debugging

- During data validation:
  - Obtain the current data file line and column number from the trace back.
  - Verify that the record has the proper format.
- During cross-referencing:
  - From the message, identify the routine where the problem occurs and determine variable type being cross-checked.

Modeling Strategies (cont.)

During simulation:

- **Identify flight ID and location at the time of the error.**
- **Turn group trace statements on for this time period to improve the ability to identify error.**
- **If necessary, turn on individual trace statements for this time period.**