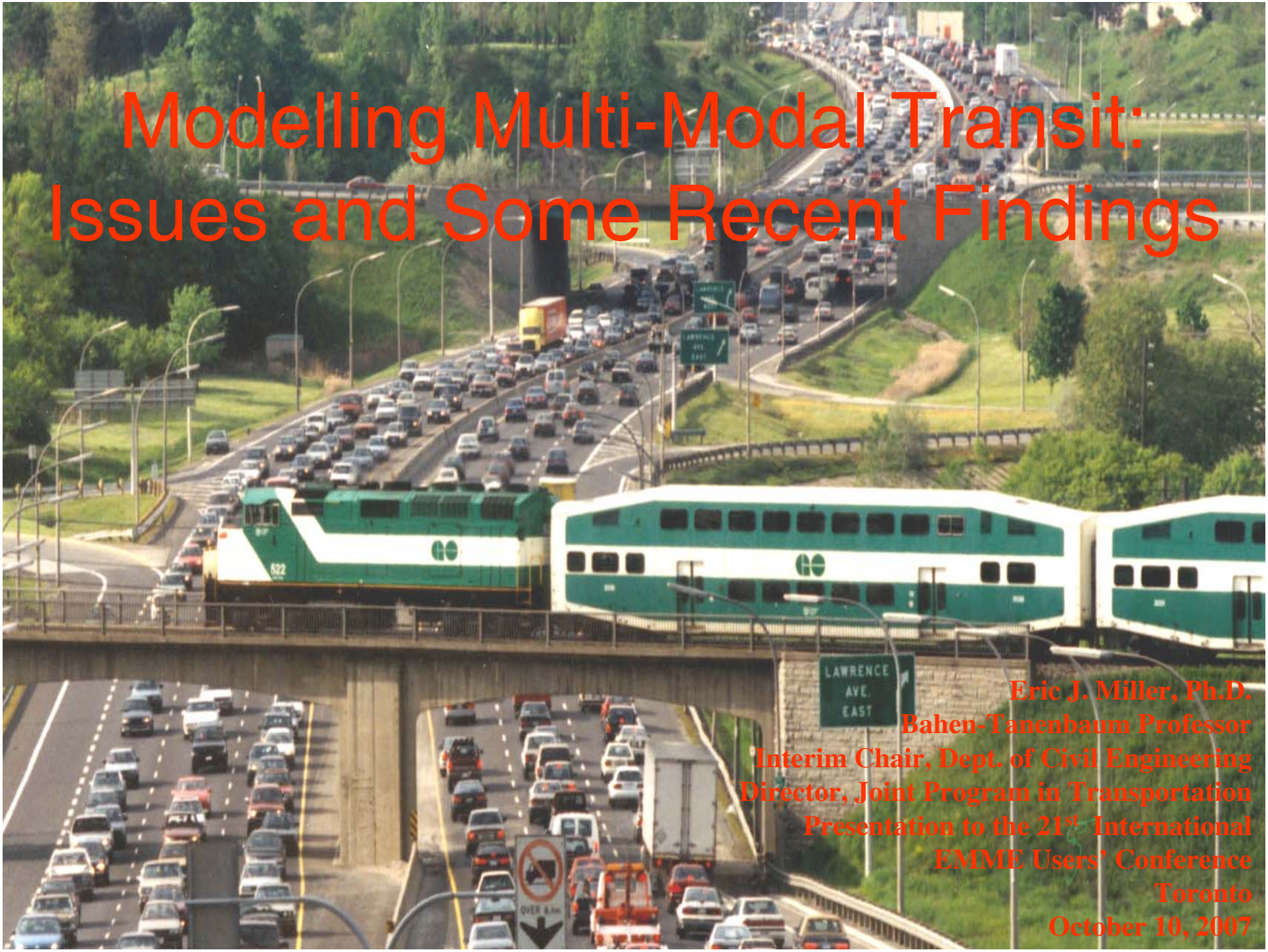
Modelling Multi-Modal Transit: Issues and Some Recent Findings



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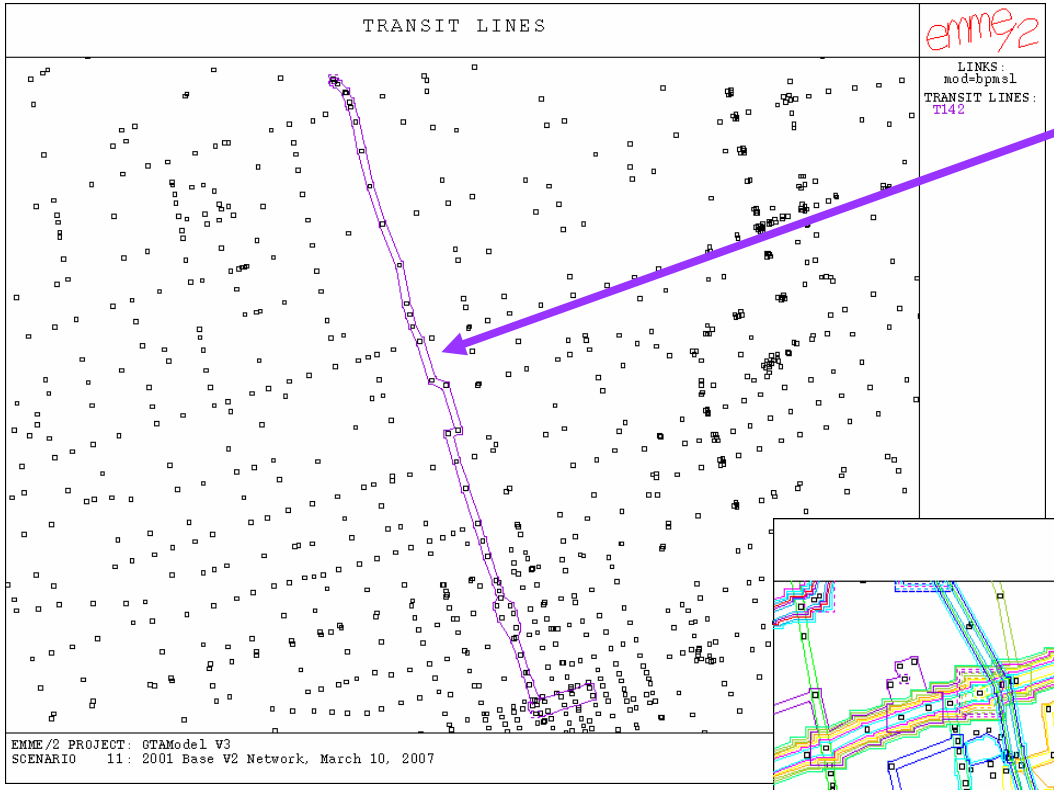
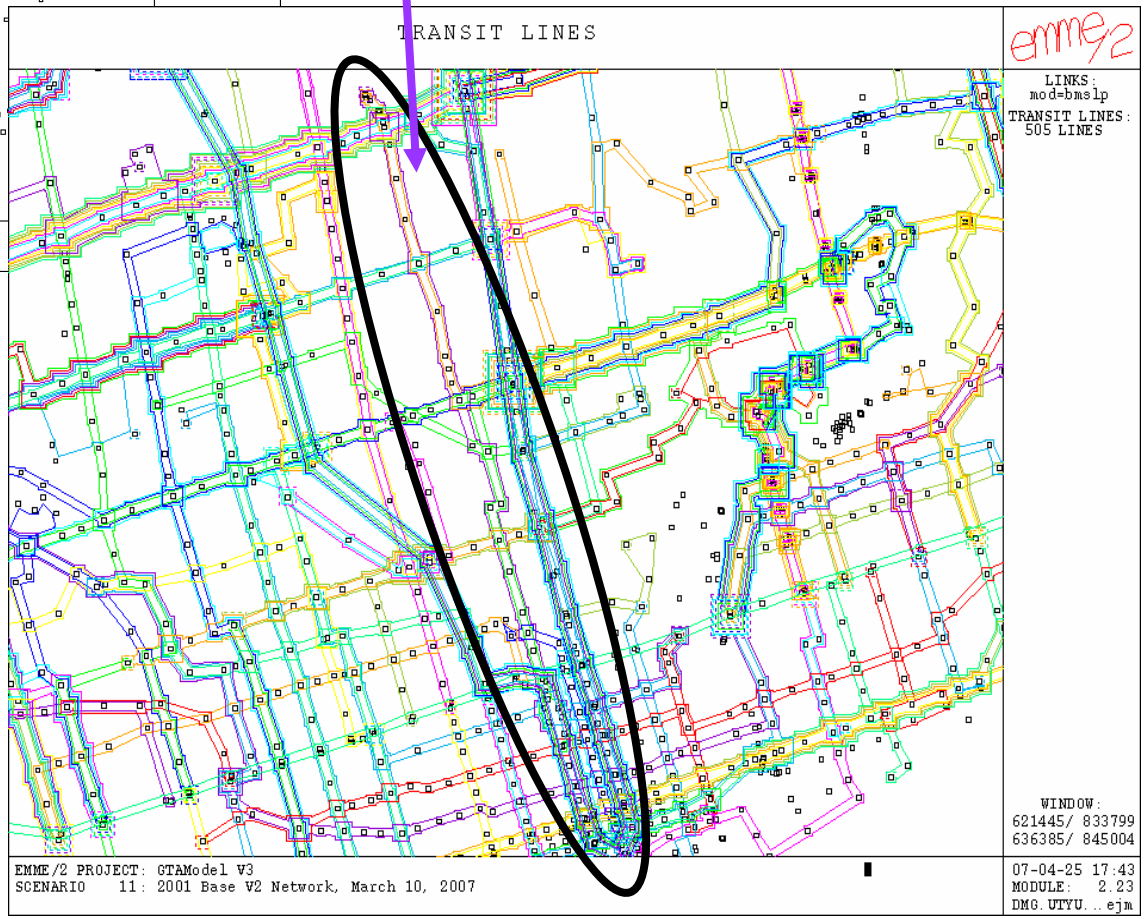
Presentation to the 21st International EMME Users' Conference
Toronto
October 10, 2007



TTC premium bus route (double fare)
T142, Avenue Road

T142 embedded within the overall transit network



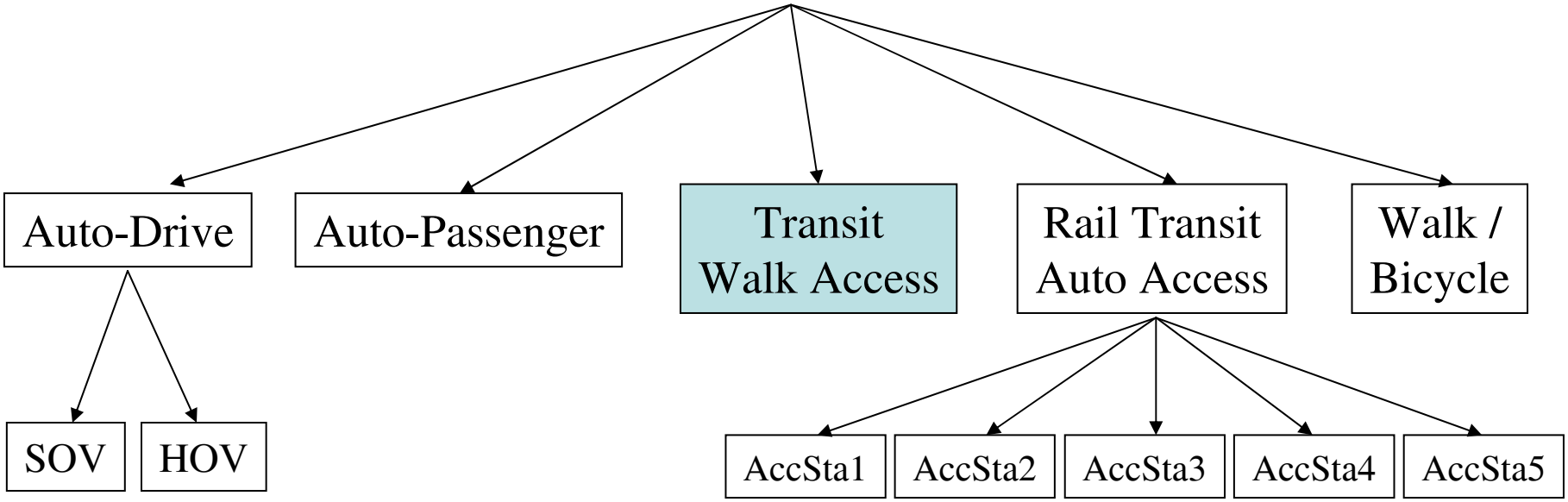
The GTA transit network is a complex system consisting of:

- Multiple and overlapping service areas
- Multiple fare systems
- Multiple “sub-modes” (bus, streetcar, subway, etc.)
- Multiple access modes (walk, auto-drive, etc.)
- Competing/parallel services (often provided by the same operator)

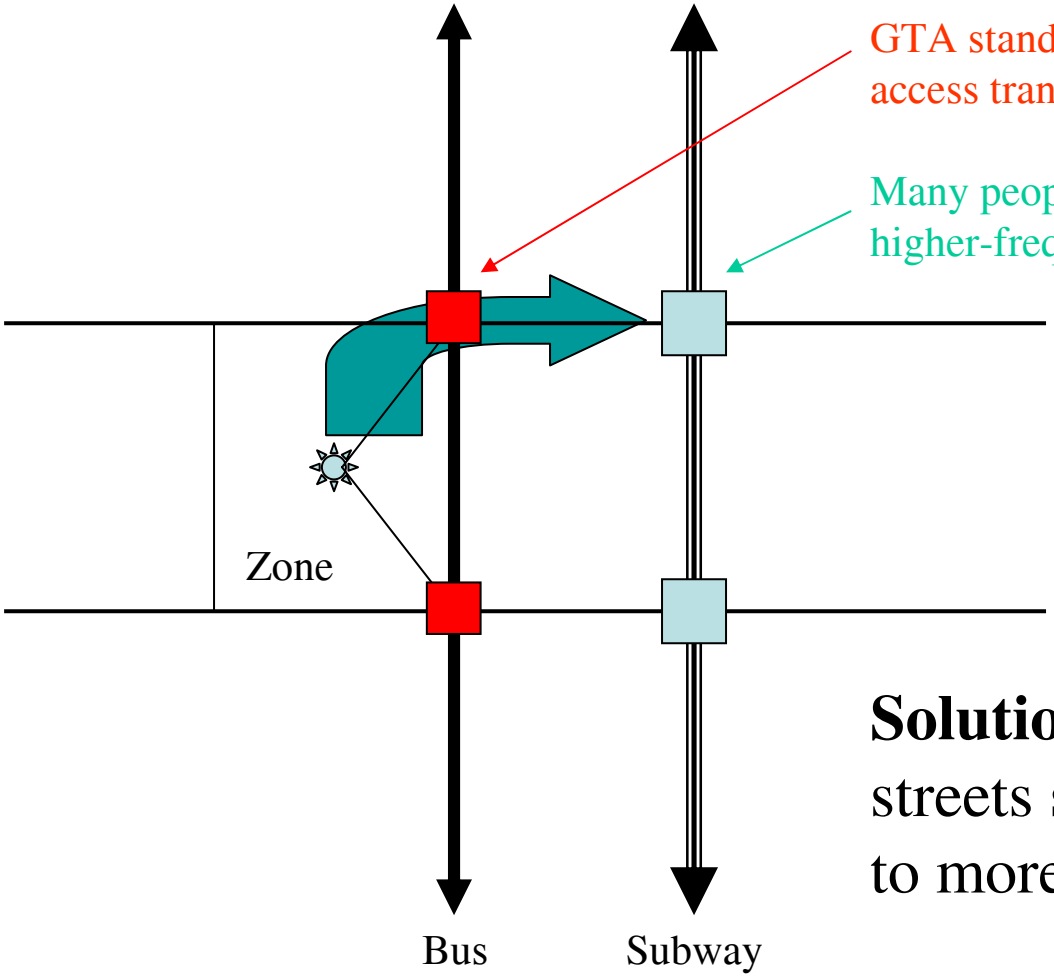
Dealing with these complexities requires a coordinated, consistent approach.

Selected Approach

- Incorporate time value of transit fares into transit network and do generalized time transit assignments.
- Treat transit sub-modes as alternative paths through the transit network, rather than as different modes in the mode choice model.
- Allow “walk on network” so that transit riders do not need to access the closest transit stop.
- Explicitly model auto access to higher-order transit (subway & commuter rail) as a separate mode.

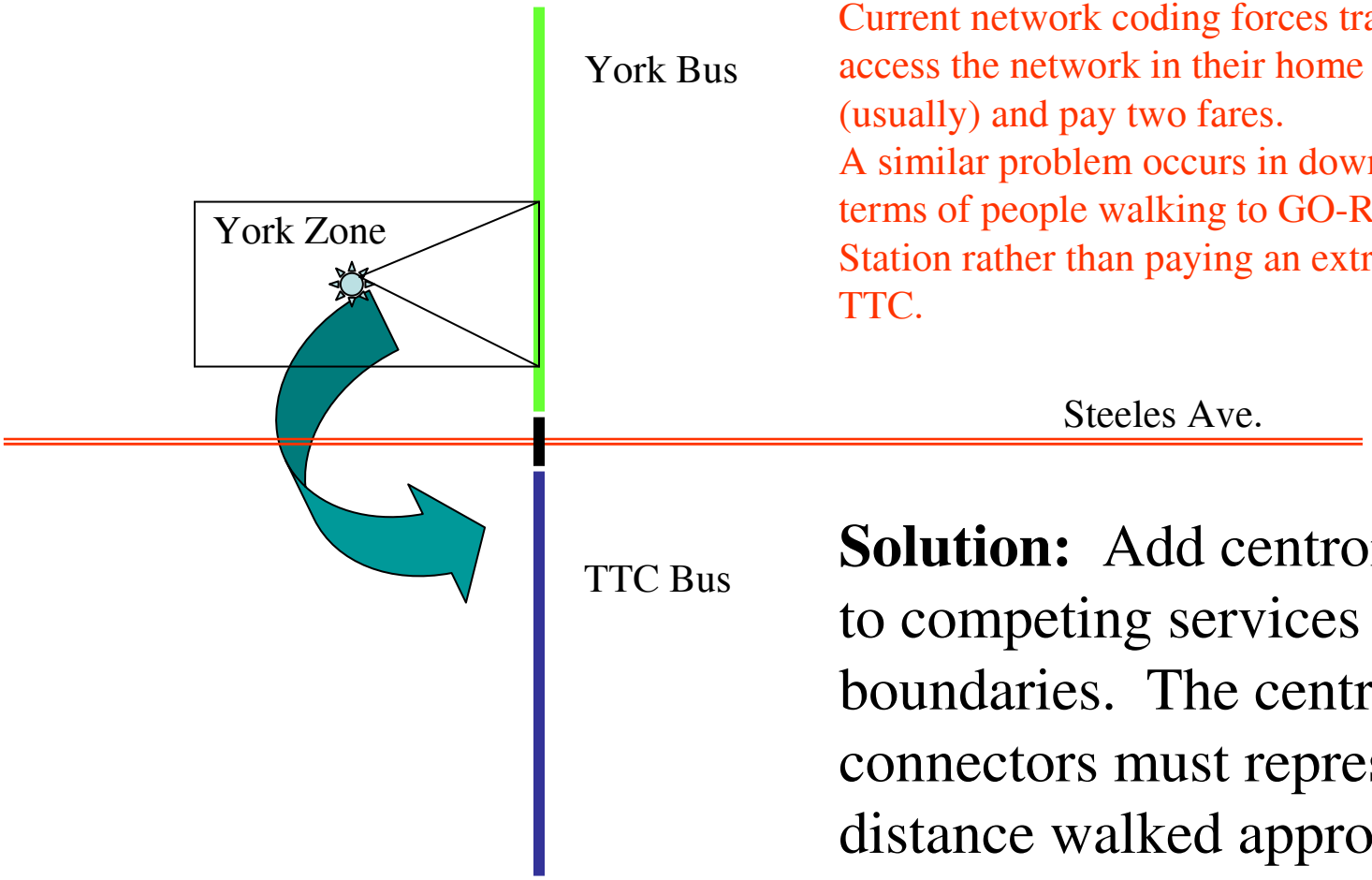


Mode Choice Structure



Solution: Allow walk mode on streets so that transit users can walk to more distant transit line.

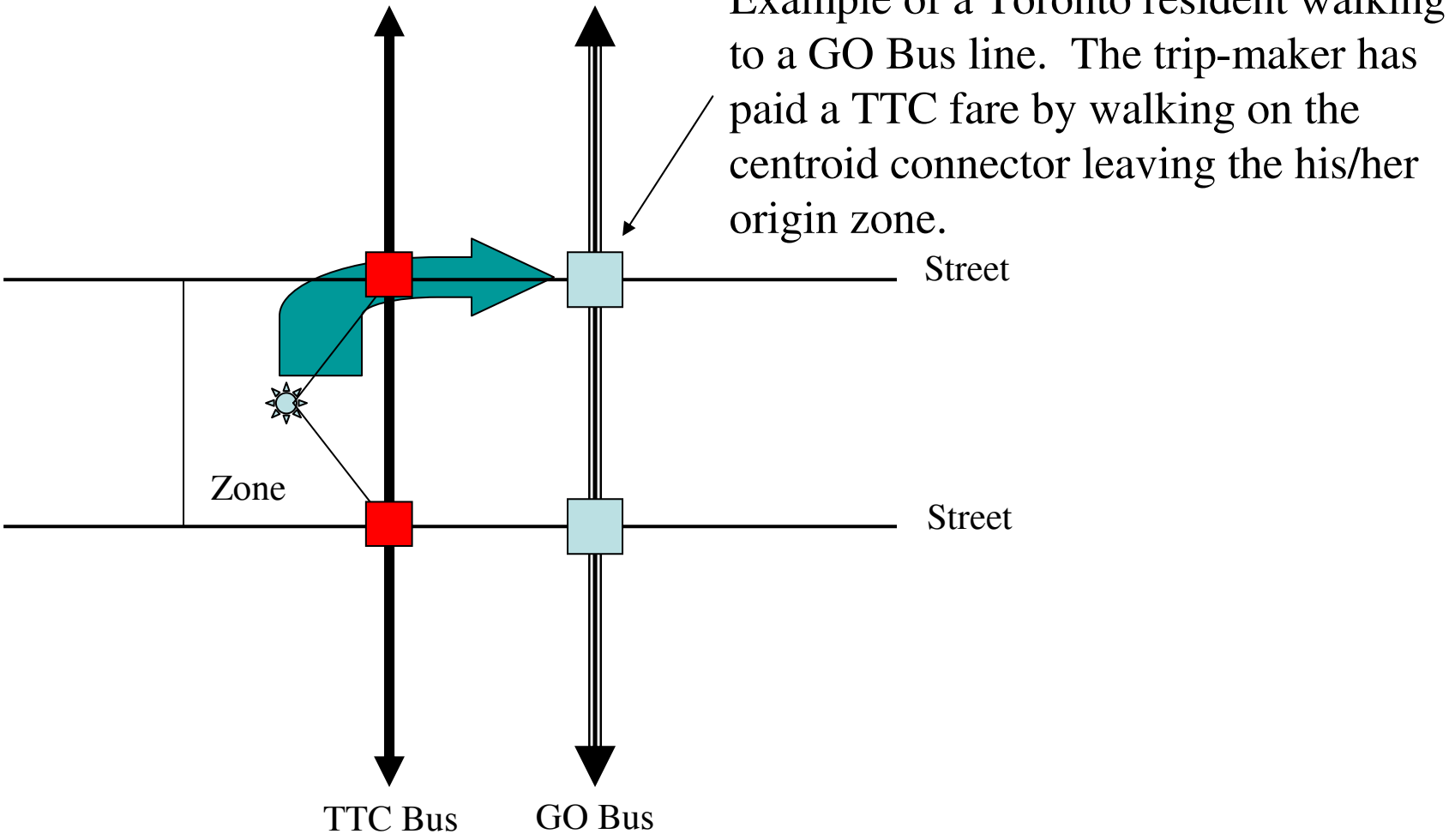
Walk Access to Transit I: "Walk on Network"



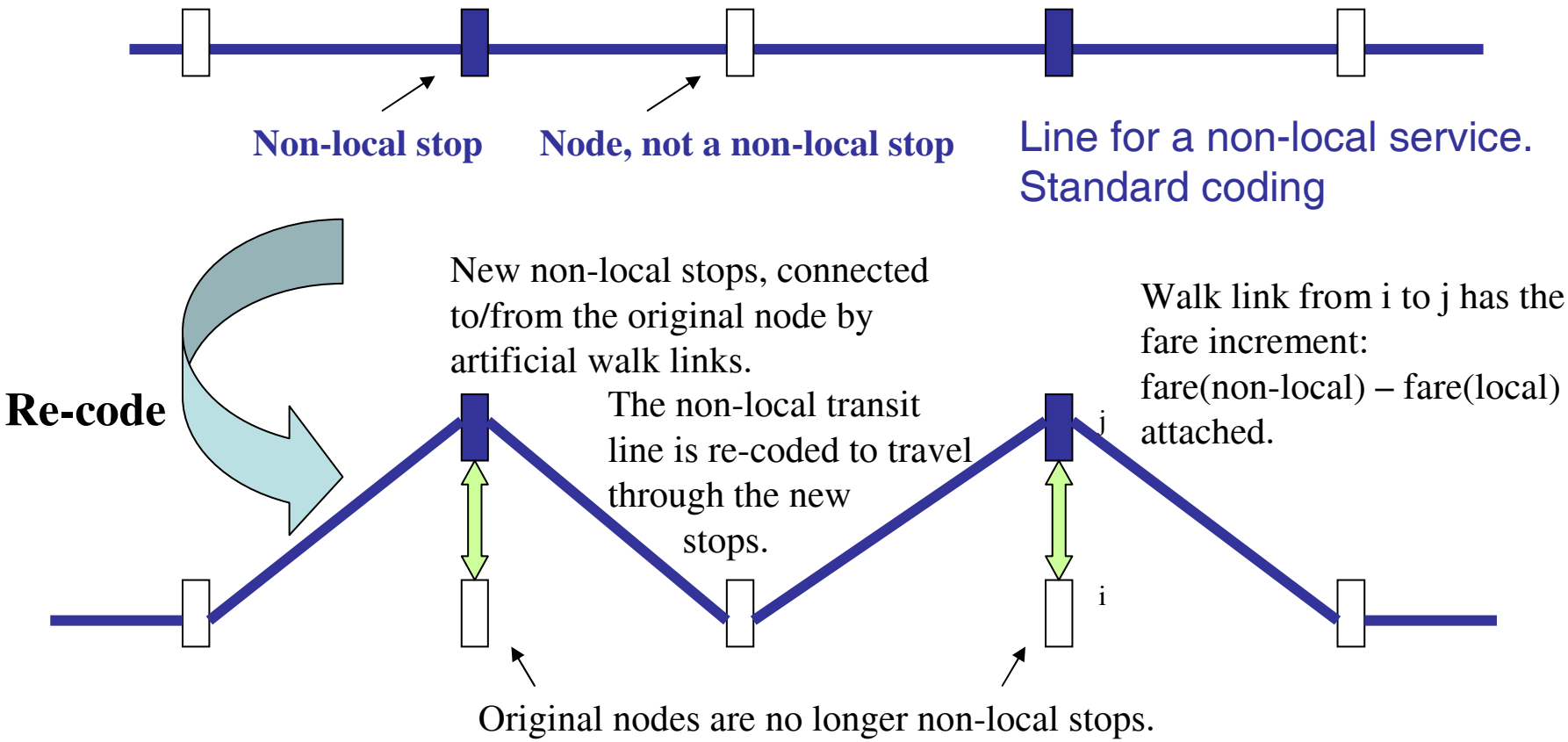
Current network coding forces transit users to access the network in their home service area (usually) and pay two fares.
A similar problem occurs in downtown Toronto in terms of people walking to GO-Rail at Union Station rather than paying an extra fare to use the TTC.

Solution: Add centroid connectors to competing services across fare boundaries. The centroid connectors must represent the extra distance walked appropriately.

Walk Access to Transit II: Crossing Fare Boundaries



Walk on Network III: Walking to a "Non-Local" Service



Re-Coding to Deal with Walk on Network to a "Non-Local" Service

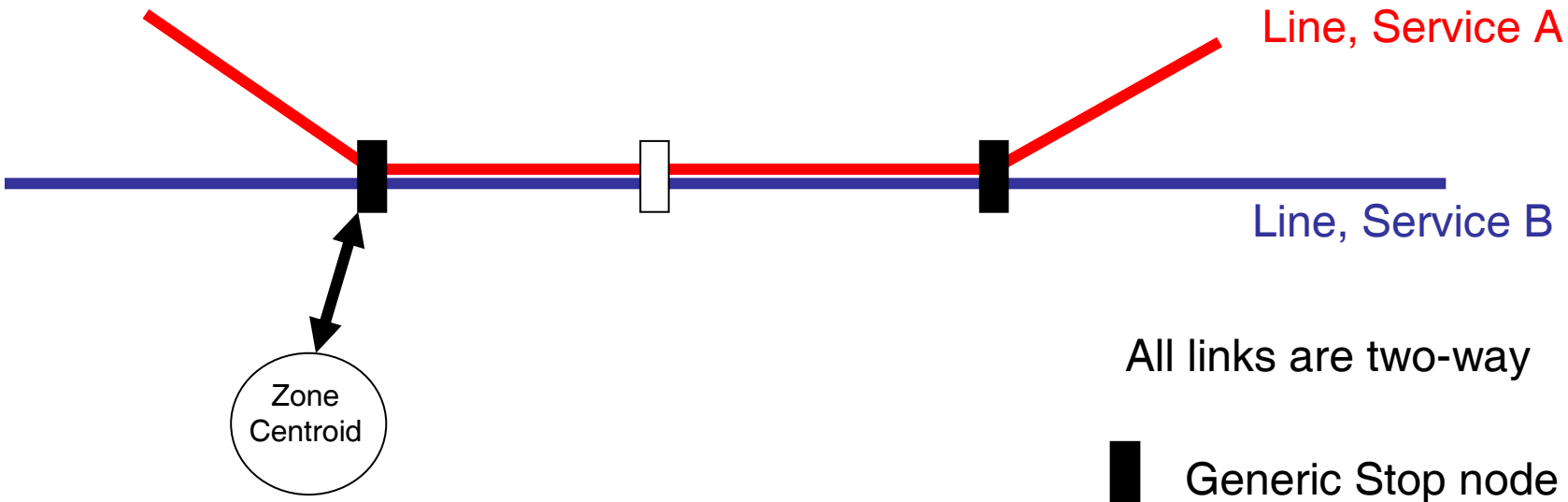
Fare-Based Transit Assignment

- In order to do fare-based transit assignment, one must code in:
  - Initial access fares.
  - Transfer fares when transferring from one service to another.
  - Fare increments when cross a fare zone boundary on the same service.

Initial Transit Fare

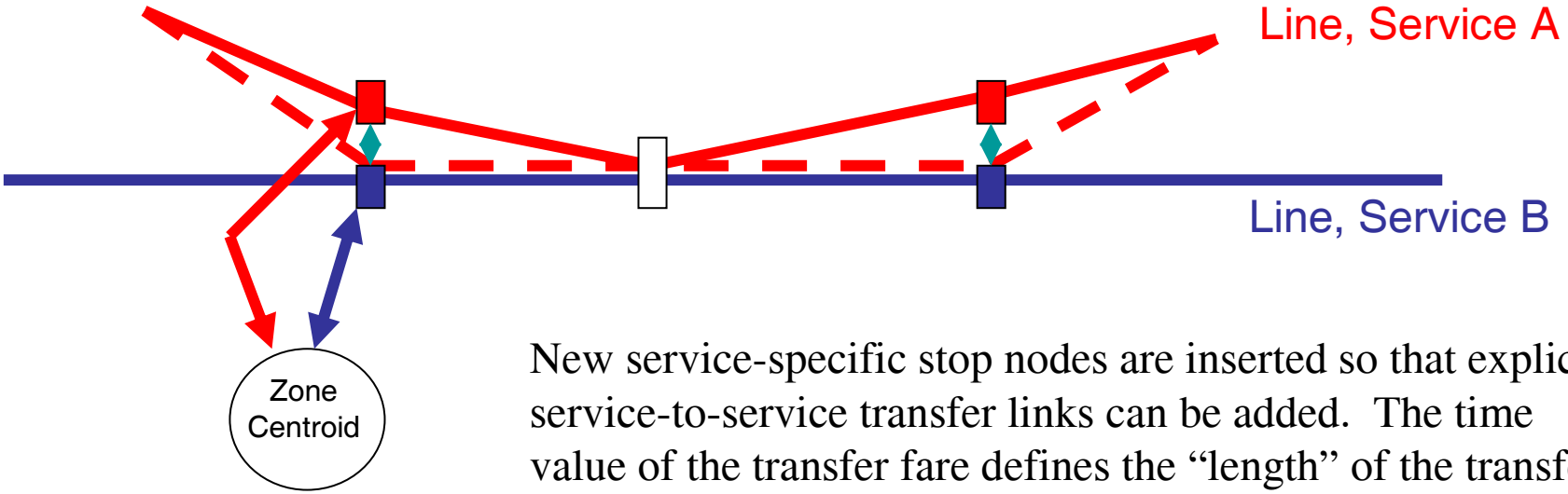
- Ideally, one would want to attach a transit fare to the “first boarding” of a given transit service.
- Unfortunately, EMME/2 does not distinguish between first and subsequent boardings.
- Therefore, centroid connectors in the “access” direction must be coded with the time-value of the initial fare.
- This creates some complications in skimming access walk times and in dealing with walk access representation.

Transfer Fares



Typical Base Network Coding

The standard GTA transit network coding permits free transfers between services since they share the same stop nodes.



All links are two-way

New service-specific stop nodes are inserted so that explicit service-to-service transfer links can be added. The time value of the transfer fare defines the "length" of the transfer link in each direction.

Note that only 1 service needs to be recoded and only 1 new node per service needs to added. The new nodes are off-set slightly from the original nodes to improve legibility.

Service B stop node

Non-stop node

Service B centroid connector

A <-> B transfer link

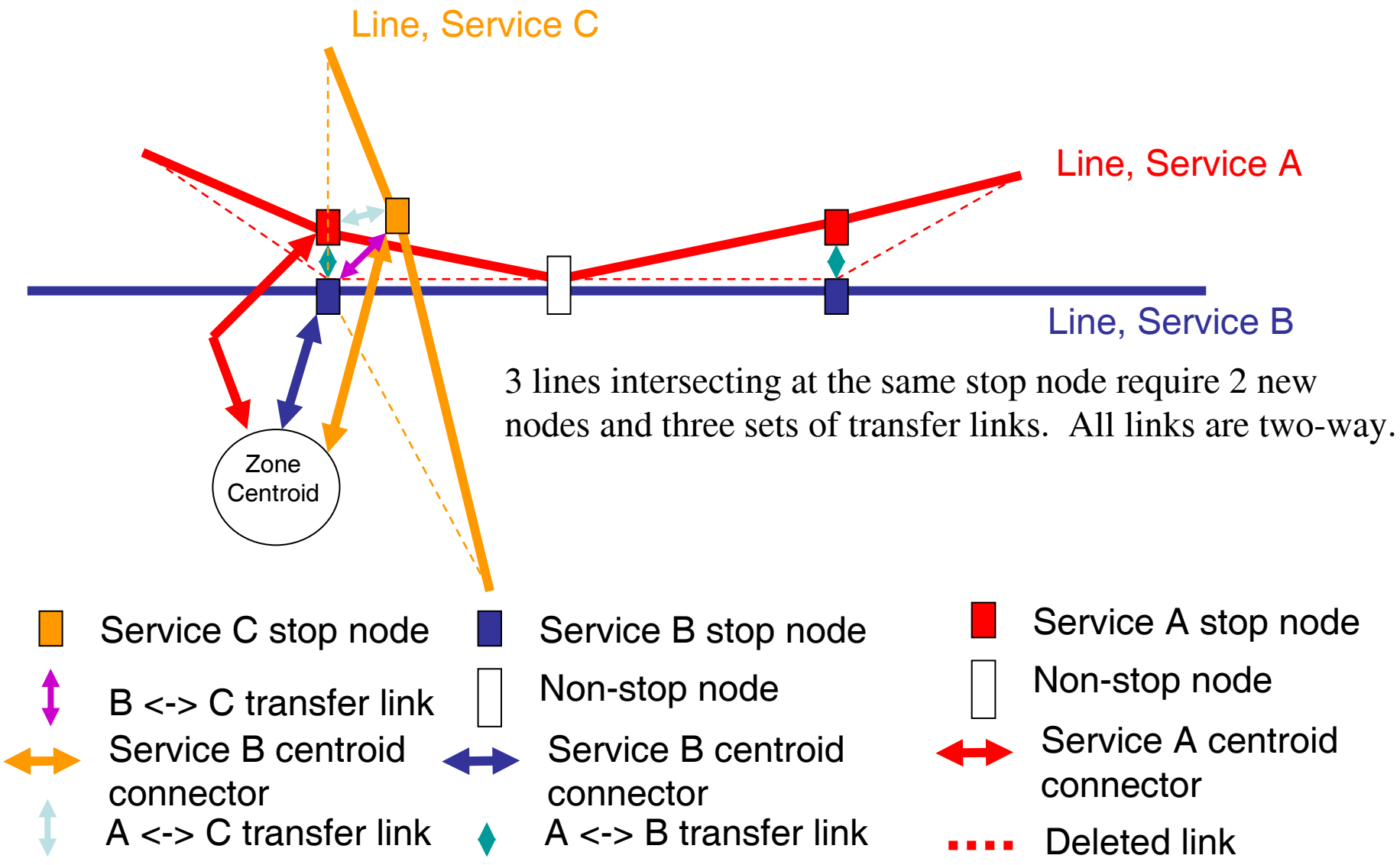
Service A stop node

Non-stop node

Service A centroid connector

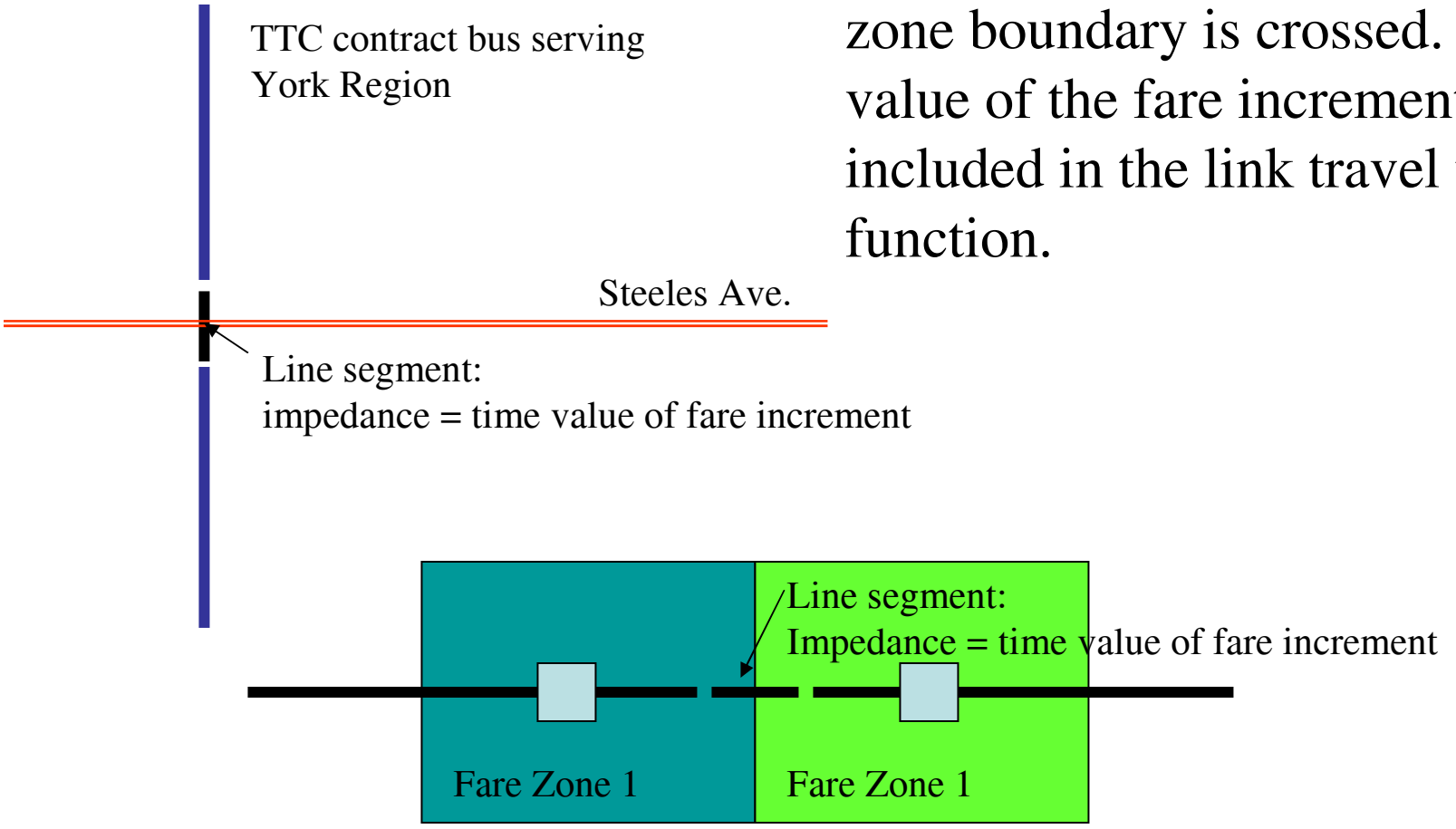
Deleted link

Re-coding Transfers Between Two Operators



Re-coding Transfers, Three Operator Case

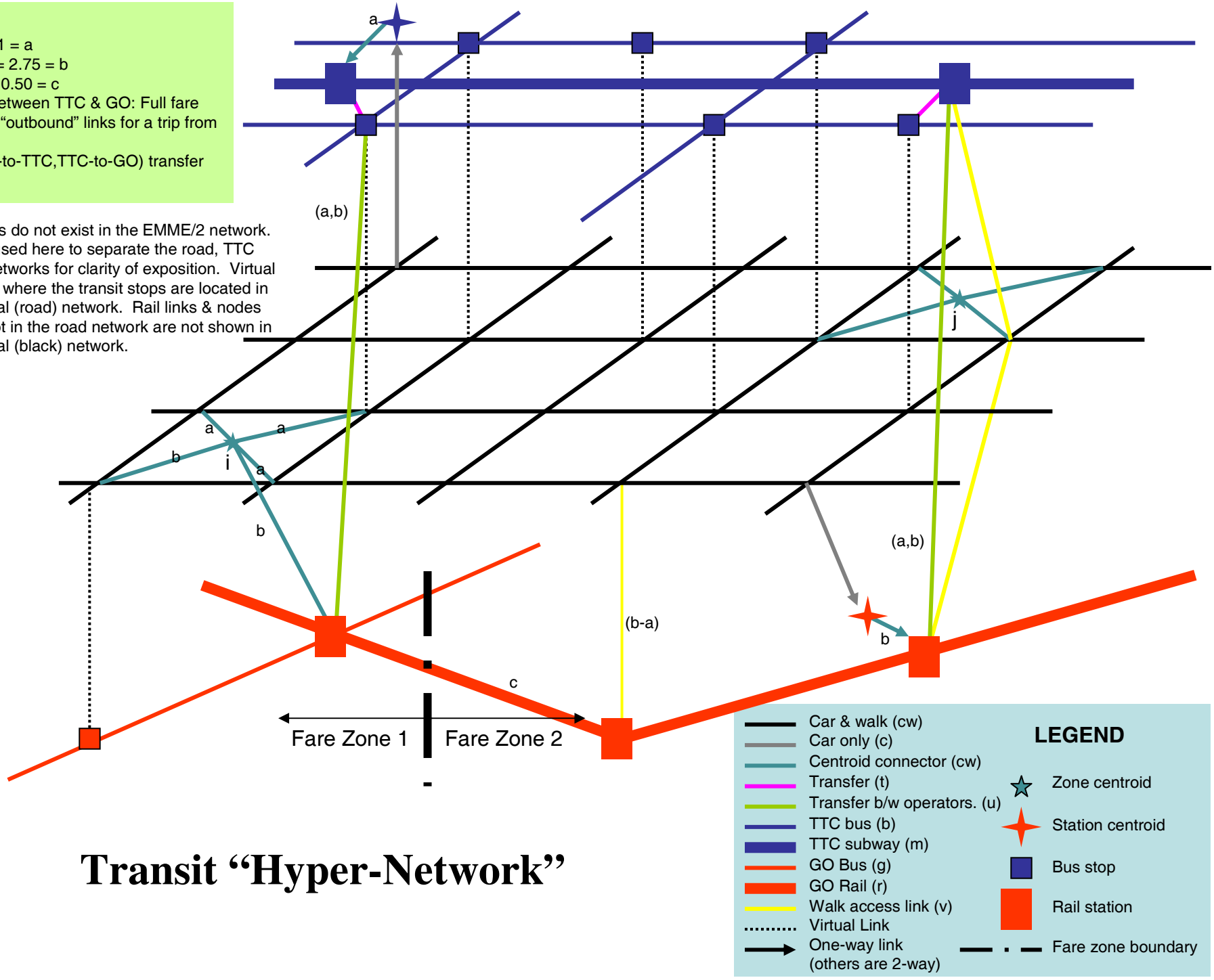
A **line segment user field** is coded at each segment at which a fare zone boundary is crossed. The time value of the fare increment is included in the link travel time function.



Incremental Fare Due to Crossing a Fare Zone Boundary
(No transfer between services)

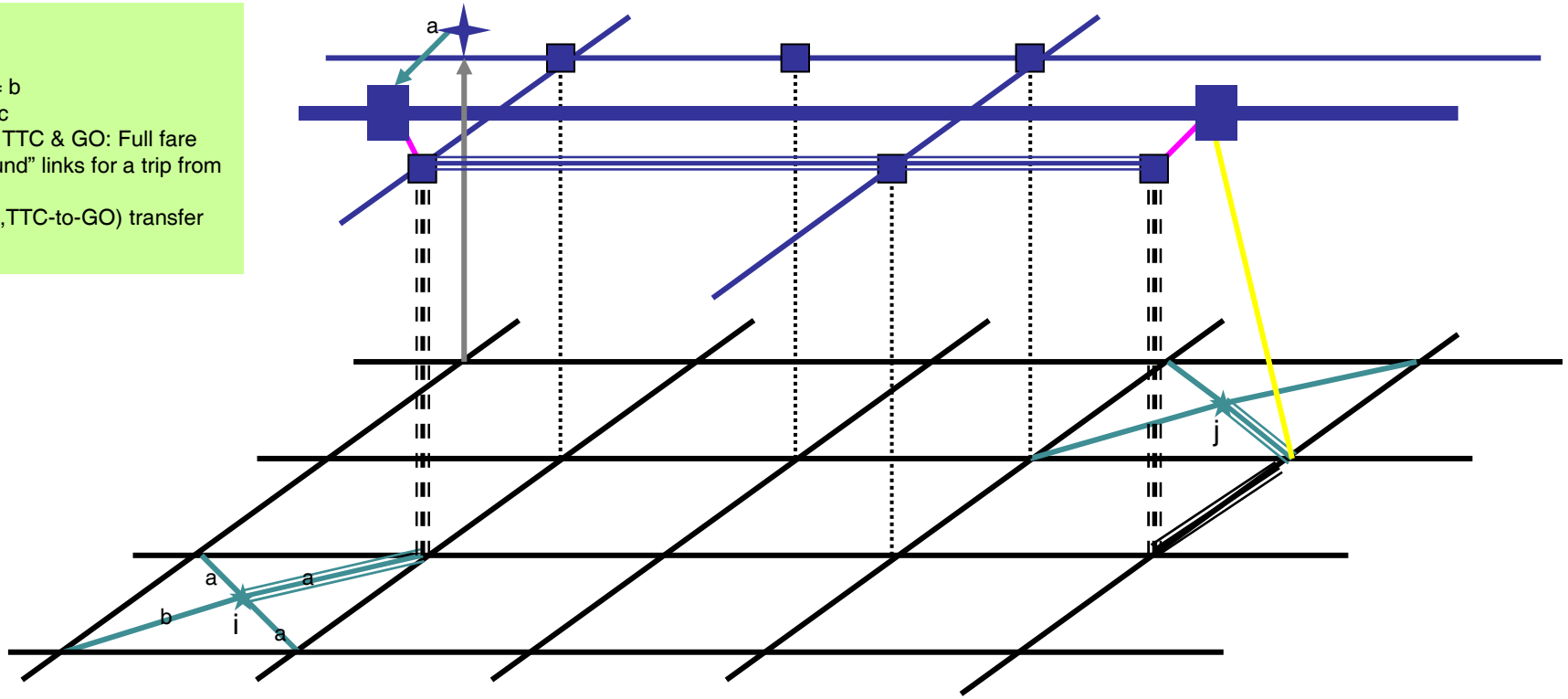
Fares:
TTC = 1.91 = a
GO Base = 2.75 = b
GO(1,2) = 0.50 = c
Transfer between TTC & GO: Full fare
Shown on "outbound" links for a trip from i to j only.
(a,b): (GO-to-TTC,TTC-to-GO) transfer fares.

Virtual links do not exist in the EMME/2 network. They are used here to separate the road, TTC and GO networks for clarity of exposition. Virtual links show where the transit stops are located in the physical (road) network. Rail links & nodes that are not in the road network are not shown in the physical (black) network.



Transit "Hyper-Network"

Fares:
TTC = 1.91 = a
GO Base = 2.75 = b
GO(1,2) = 0.50 = c
Transfer between TTC & GO: Full fare
Shown on "outbound" links for a trip from i to j only.
(a,b): (GO-to-TTC,TTC-to-GO) transfer fares.



Example TTC – walk access path through the network from i to j. Fare = $1.91.

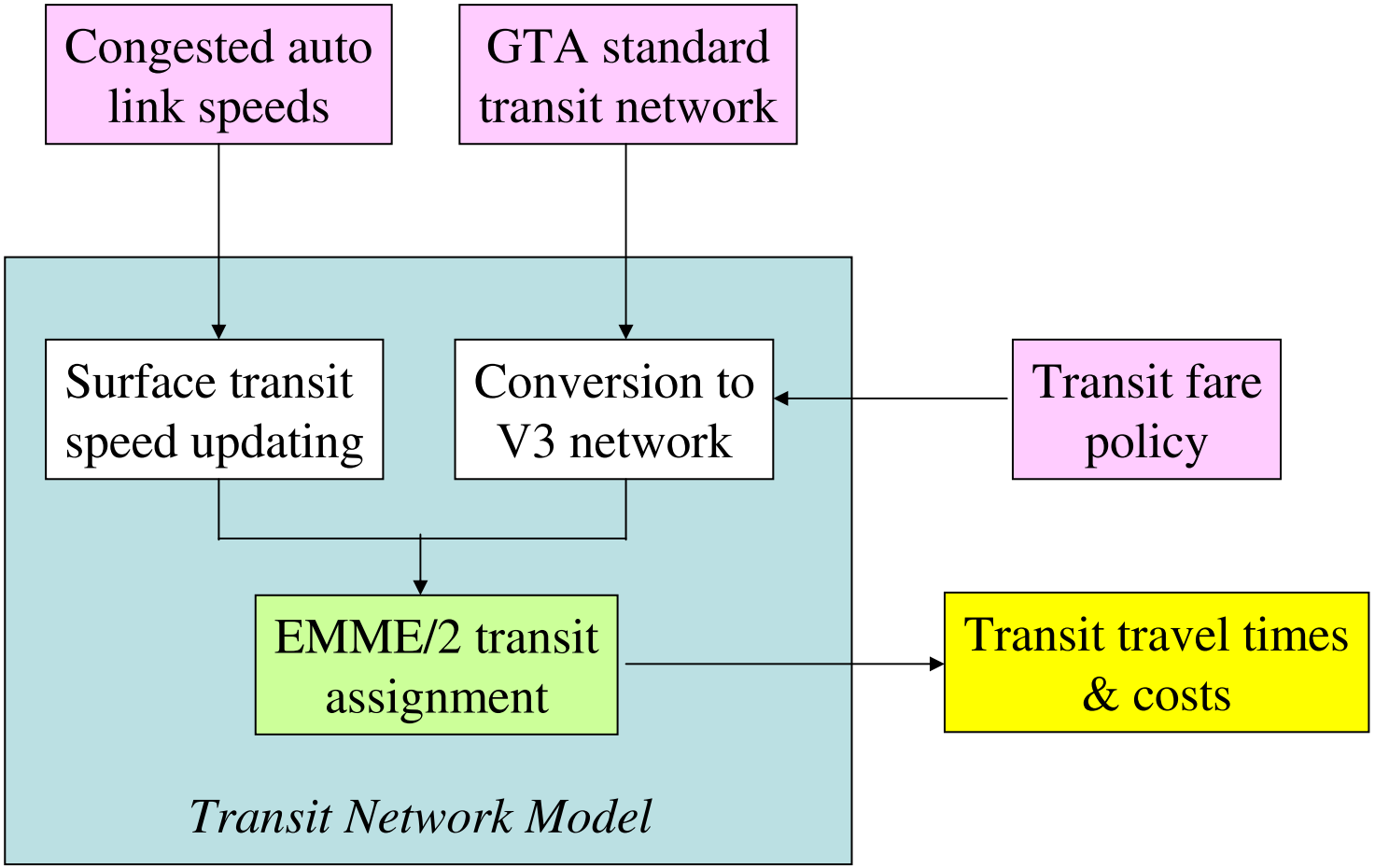
One Feasible Path Through the Transit "Hyper-Network"

Virtual links do not exist in the EMME/2 network. They are used here to separate the road, TTC and GO networks for clarity of exposition. Virtual links show where the transit stops are located in the physical (road) network. Rail links & nodes that are not in the road network are not shown in the physical (black) network.

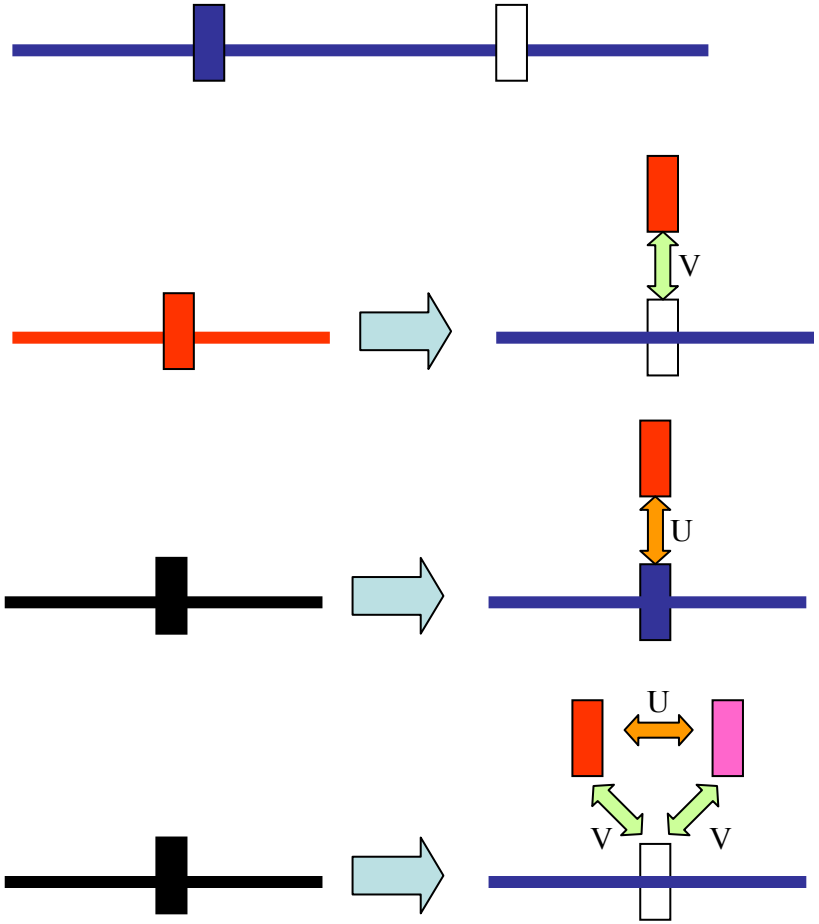
- Car & walk (cw)
- Car only (c)
- Centroid connector (cw)
- Transfer (t)
- Transfer b/w operators. (u)
- TTC bus (b)
- TTC subway (m)
- GO Bus (g)
- GO Rail (r)
- Walk access link (v)
- Virtual Link
- One-way link (others are 2-way)
- Selected link on path
- Zone centroid
- Station centroid
- Bus stop
- Rail station
- Fare zone boundary

Automated Network Coding

- The coding of the extra links and nodes required for fare-based assignment would be extremely onerous and error-prone for human analysts to undertake using the usual network coding/editing features of EMME.
- A macro has been developed that automates this process.
- This macros takes as its inputs:
  - A standard network, as constructed using the GTA coding standard.
  - The transit fare policies for the 8 GTA transit services.
- The output of this macro is a modified network and set of transit lines that incorporates all the features described above for fare-based transit assignment.



Transit Network Model Sub-System

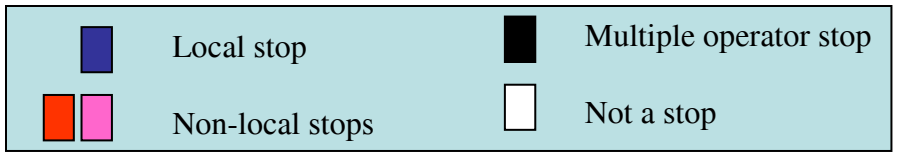


1. Not a stop or a local operator stop only.

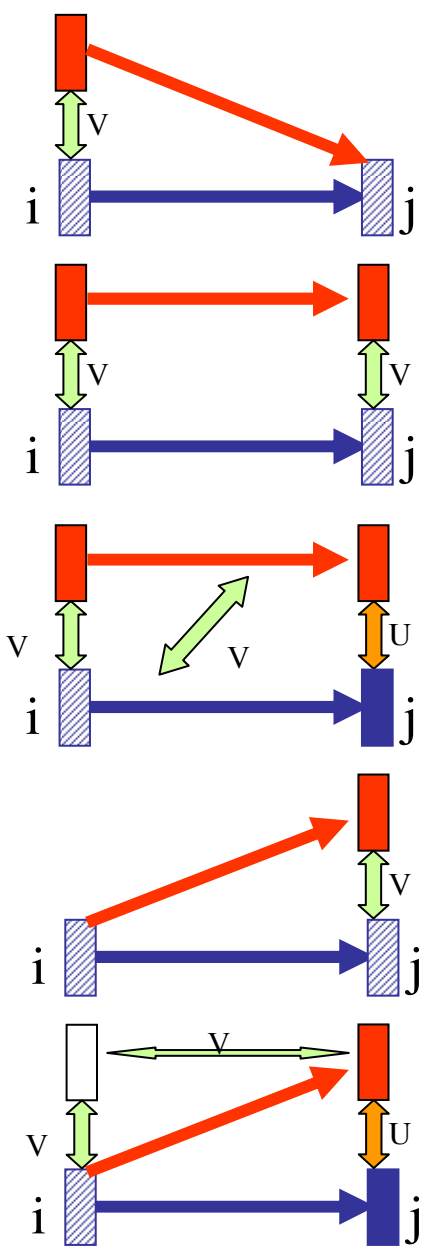
2. A non-local operator stop only. Create a new stop node; connect it to the original stop by "v-links" (walk access link).

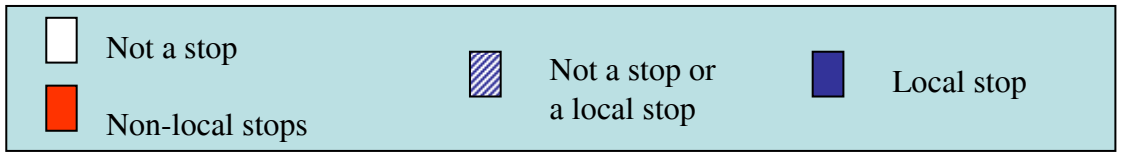
3. Local & non-local stops. Create a new non-local stop node; connect it to the local stop by "u-links" (transfer link).

4. More than one non-local stop, not a local stop. Create new non-local stops; connect to local walk network by v-links; connect to each other with u-links.



Four Cases for Creating New Nodes and Connector Links





1. New transit link from new non-local stop to a local/non-stop.

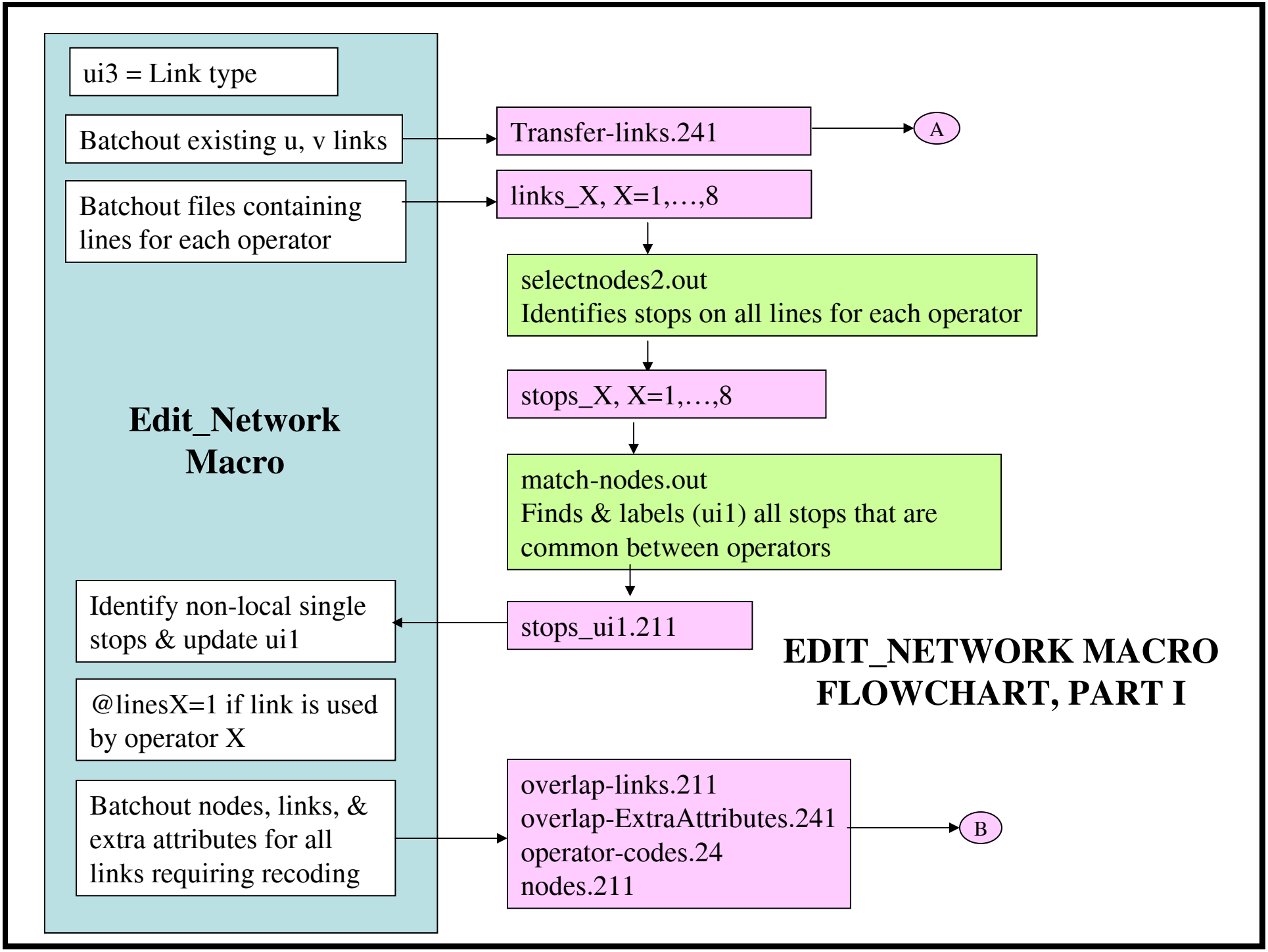
2. New transit link from new non-local to new non-local stop.

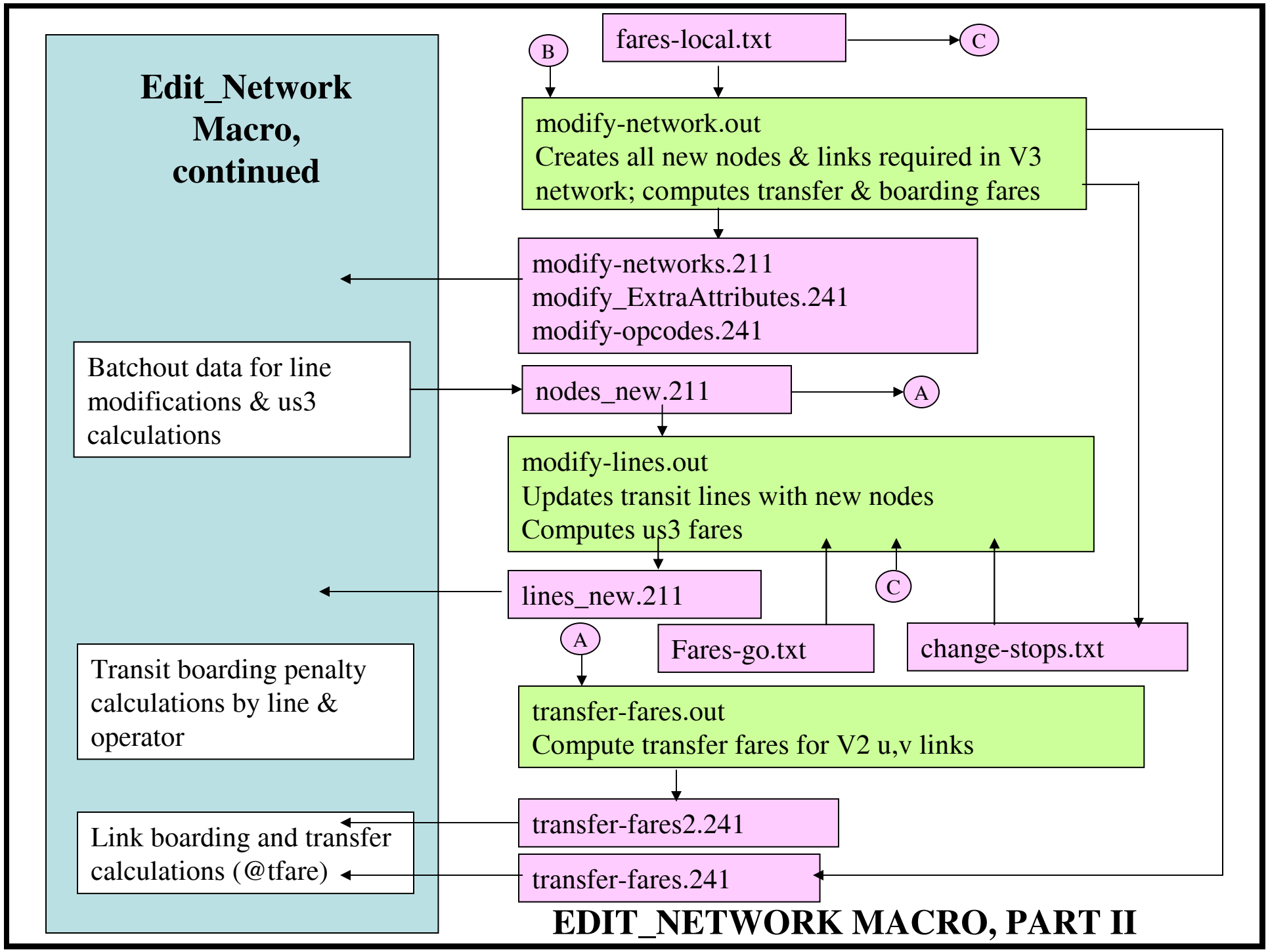
3. New transit link between the new non-local stops. V-links providing walk access to the "u-stop".

4. New transit link from the local/non-stop to the new non-local stop.

5. New transit link from the local/non-stop to the new non-local stop. New node with v-links to provide walk access to the "u-stop".

Five Cases for Transit Line Re-Coding


ui3 = Link type
Batchout existing u, v links
Batchout files containing lines for each operator
Edit_Network Macro
Transfer-links.241
A
links_X, X=1,…,8
selectnodes2.out
Identifies stops on all lines for each operator
stops_X, X=1,…,8
match-nodes.out
Finds & labels (ui1) all stops that are common between operators
stops_ui1.211
Identify non-local single stops & update ui1
@linesX=1 if link is used by operator X
Batchout nodes, links, & extra attributes for all links requiring recoding
overlap-links.211
overlap-ExtraAttributes.241
operator-codes.24
nodes.211
B
EDIT_NETWORK MACRO FLOWCHART, PART I


Edit_Network Macro, continued
B
fares-local.txt
C
modify-network.out
Creates all new nodes & links required in V3 network; computes transfer & boarding fares
modify-networks.211
modify_ExtraAttributes.241
modify-opcodes.241
Batchout data for line modifications & us3 calculations
nodes_new.211
A
modify-lines.out
Updates transit lines with new nodes
Computes us3 fares
lines_new.211
C
A
Fares-go.txt
change-stops.txt
Transit boarding penalty calculations by line & operator
transfer-fares.out
Compute transfer fares for V2 u,v links
transfer-fares2.241
Link boarding and transfer calculations (@tfare)
transfer-fares.241
EDIT_NETWORK MACRO, PART II

Add time value of boarding & transfer fares (@tfare) (expressed as distance) to centroid connectors & u,v links

Define transit time functions to update surface transit speeds & add time value of incremental zone fares (us3)

ASSIGNMENT 1:
Additional attribute calculation: Collect incremental zone fares (us3) in mf07

ASSIGNMENT 2:
Additional attribute calculation: Collect boarding & transfer fares (@tfare) in mf08

Recover transit times & costs:
ivtt: mf01 = mf01 – mf07*tvalm
twalk: mf02 = mf02 – mf08*tvalm
tfare: mf06 = mf07 + mf08

Determine transit feasibility for each O-D pair. Feasible if:
1. ivtt+twalk+twait < 200 min.
2. twalk < 50 min.
3. twait < 40 min.
Set times/costs = 0 for infeasible O-D/s

TRANSIT ASSIGNMENT MACRO MAIN TASKS

Transit Assignment Parameters

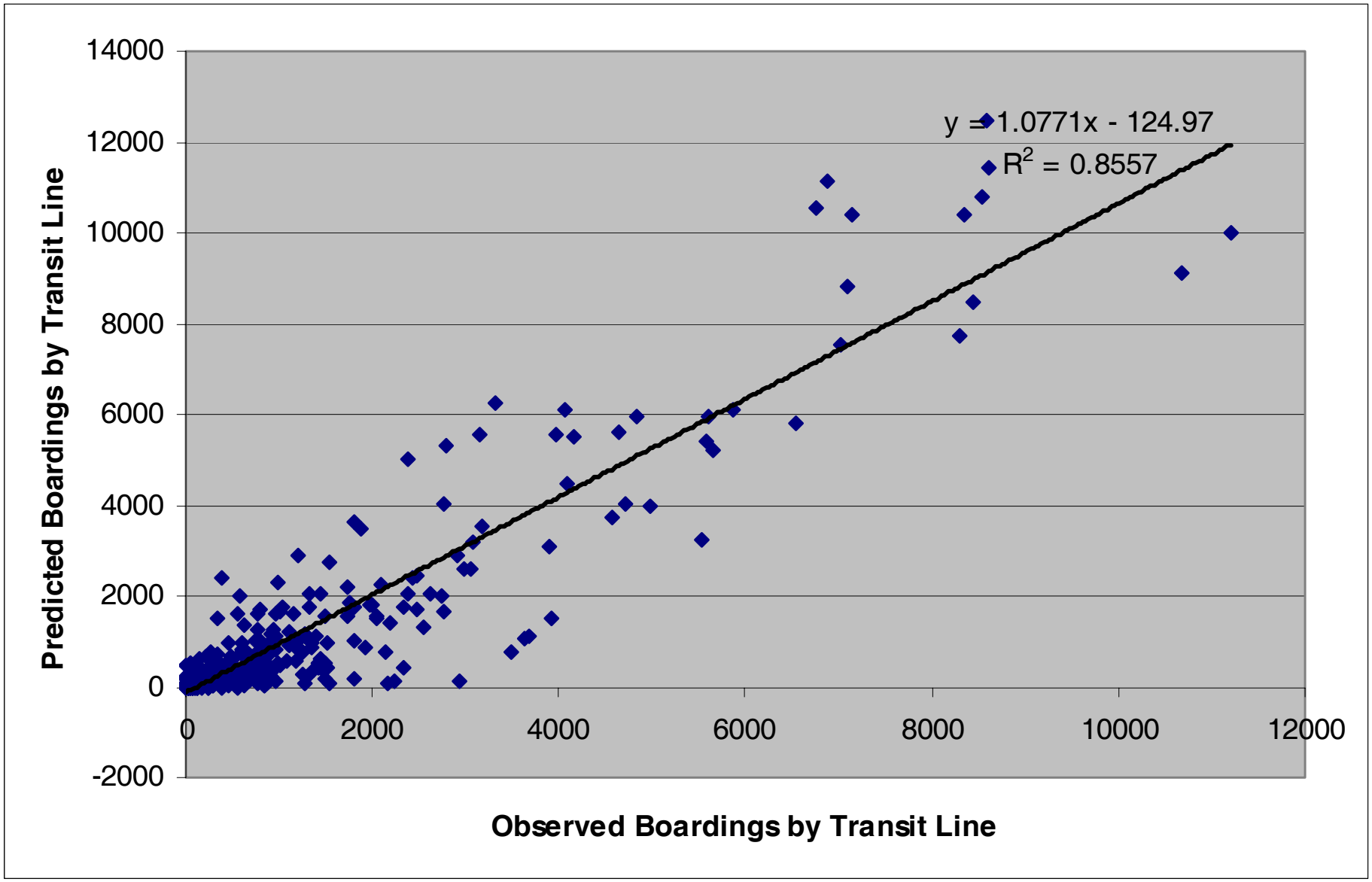
In addition to the normal time-related assignment parameters, transit fares and the time-value of money are input parameters. Boarding time penalties by transit operator are also used to capture service reliability and other qualitative factors associated with each service.

The assignment parameters were calibrated by comparing predicted and observed boardings by route and service.

EMME/2			
No.	**Name**	**Value**	**Description**
ms03	wlkspd	4.0	Walk speed (km/hr)
ms04	wttfac	0.5	Wait time factor
ms05	wtwait	2.0	Wait time weight
ms06	wtwalk	1.0	Walktime weight
ms07	wtbrd	1.0	Boarding time weight
ms08	tvalm	8.0	Transit time value of money (min/$)
ms31	tbfare	1.91	Toronto base fare ($)
ms32	gofare	2.75	GO Transit base fare ($)
ms33	ybfare	1.92	York base fare ($)
ms34	pbfare	1.75	Peel base fare ($)
ms35	hlfare	1.87	Halton base fare ($)
ms36	hmfare	1.68	Hamilton base fare ($)
ms37	dbfare	1.75	Durham base fare ($)
ms41	bdttcm	0.0	TTC subway boarding time (min)
ms42	bdttcb	2.0	TTC regular bus boarding time (min)
ms43	bdttcp	0.0	TTC premium bus boarding time (min)
ms44	bdttcs	2.2	TTC streetcar boarding time (includes mode=l) (min)
ms45	bdgor	0.0	GO Train boarding time (min)
ms46	bdgob	10.0	GO Bus boarding time (min)
ms47	bddurb	0.0	Durham Region bus boarding time (min)
ms48	bdyrkb	6.4	York Region bus boarding time (min)
ms49	bdplb	3.1	Peel Region bus boarding time (min)
ms50	bdhalb	4.1	Halton Region bus boarding time (min)
ms51	bdhamb	2.3	Hamilton Region bus boarding time (min)

Fixed parameter; not calibrated

Average 2001 adult fare, as supplied by GTA transit operators



Predicted vs. Observed Boardings by Transit Line (excludes subway lines)

Observed & Predicted Boardings by Transit Service

Operator or Mode	Transit Line Boardings			
	Observed	Predicted	Error (P-O)	% Error
TTC-Total	583512	559734	-23778	-4.1%
Subway	253621	248499	-5122	-2.0%
Bus	282100	263967	-18133	-6.4%
PremBus	672	0	-672	-100.0%
Stcar-LRT	47119	47268	149	0.3%
GO-Total	20375	19817	-558	-2.7%
GO Rail	13434	12728	-706	-5.3%
GO Bus	6941	7089	148	2.1%
905-Total	74014	72845	-1169	-1.6%
Durham	7499	6913	-586	-7.8%
York	7404	7154	-250	-3.4%
Peel	38491	38188	-303	-0.8%
Halton	4695	4710	15	0.3%
Hamilton	15925	15880	-45	-0.3%
GTA-Total	677901	652396	-25505	-3.8%

GTA Root-Mean-Square Error: 912.9

Overall, the procedure under-predicts boardings slightly; this may reflect too many observed transit users being assigned to "walk all-way".

GO Rail & GO Bus predicted well in the aggregate.

TTC premium bus not handled well.

Fare-based assignment out-performs standard time-based assignment.

GO Rail Predictions by Line

	GO Rail Boardings				
Line No.	**Observed**	**Predicted**	**Error (P-O)**	**% Error**	**Line**
G9001	4651	5596	945	20.3%	Lakeshore West
G9002	1763	1868	105	6.0%	Milton
G9003	1111	1210	99	8.9%	Georgetown
G9005	362	382	20	5.5%	Bradford
G9006	884	136	-748	-84.6%	Richmond Hill
G9007	757	429	-328	-43.3%	Stouffville
G9009	3906	3107	-799	-20.5%	Lakeshore East

Western lines are over-predicted somewhat; eastern lines under-predicted somewhat.

Richmond Hill line significantly under-predicted.

GO Bus Predictions by Line

Line No.	Obs.	Pred.	Pred-Obs	Line
G6501	381	7	-374	Lakeshore West
G6502	0	202	202	Lakeshore East
G6515	0	7	7	McMaster Limited
G6516	270	171	-99	Hamilton - Toronto QEW Express
G6519	154	73	-81	Oakville - Finch Highway 403
G6521	214	158	-56	Streestville - Union Station
G6527	111	108	-3	Milton-Finch
G6531	144	10	-134	Georgetown Train Meet
G6533	36	271	235	Georgetown - York Mills
G6534	610	692	82	Brampton - York Mills
G6541	0	0	0	Orangeville - Brampton
G6542	0	29	29	Bolton - York Mills
G6546	146	78	-68	Oakville - Unionville
G6552	2342	396	-1946	Richmond Hill - Finch
G6558	959	1106	147	Richmond Hill - Finch
G6561	124	48	-76	Newmarket - Richmond Hill Train Meet
G6562	386	2373	1987	Newmarket - York Mills
G6565	36	0	-36	Barrie - Bradford Train Meet
G6566	72	11	-61	Newmarket - Yorkdale
G6568	61	0	-61	Bradford - Newmarket
G6569	68	0	-68	Beaverton - Newmarket
G6571	0	63	63	Union Station - Stouffville
G6581	56	20	-36	Port Bolster - Whitby

Lakeshore West under-predicted & Lakeshore East over-predicted somewhat – consistent with opposite errors for GO Rail.

Compensating errors for competing GO Bus routes for Georgetown and Richmond Hill routes.

Overall, performance is pretty good.

Summary

- A fare-based transit assignment has been implemented for the GTA transit network. Features include:
  - "Walk on network"
  - Sub-modes treated as route, not mode choice
  - Automated procedure for coding network details
- The procedure has been tested using 2001 TTS data.
- Performance is "not bad" but needs improvement before acceptable for operational use. More fine tuning / testing definitely possible.
- Overall, reasonably promising results to date.