DISEASE MODELING USING BIPARTITE NETWORK

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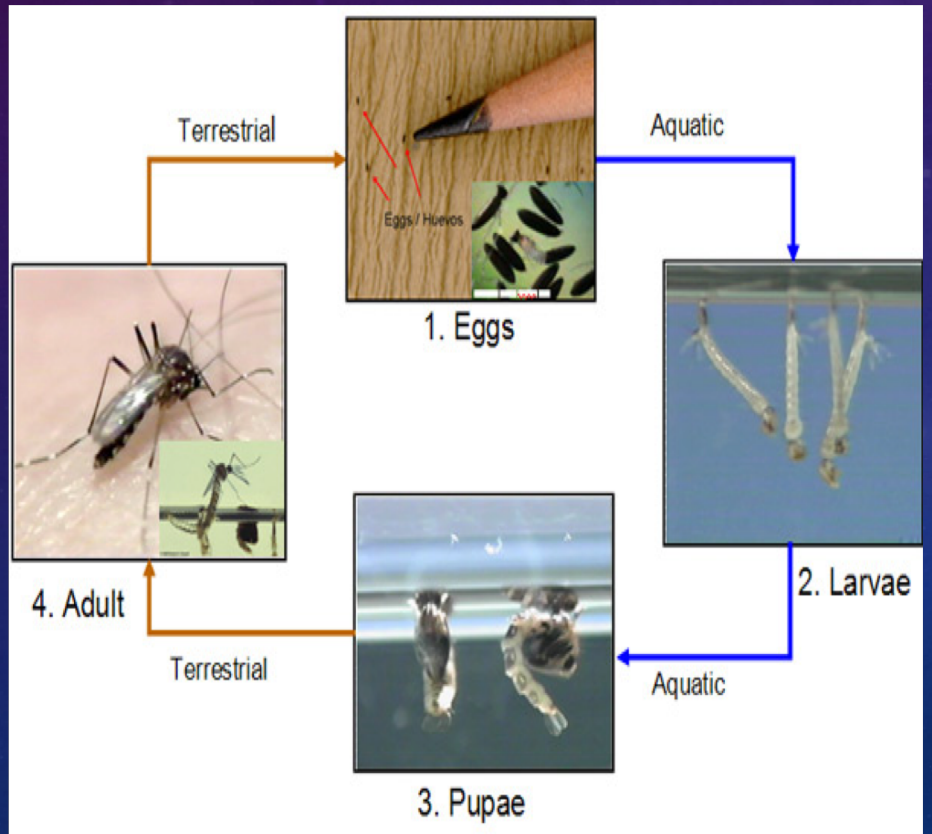
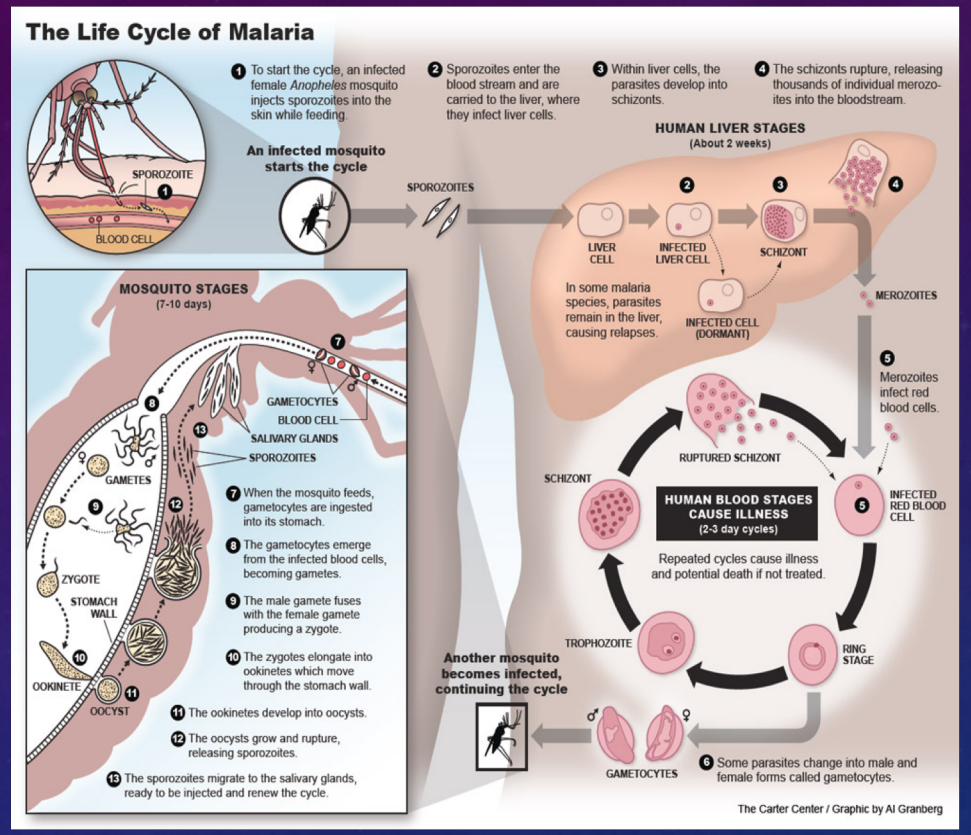
FoCuS IT
focus on individual transformation

MOTIVATION

MOSQUITO-BORNE DISEASE





Malaria, Dengue, Chikungunya, West-Nile virus, Japanese Encephalitis

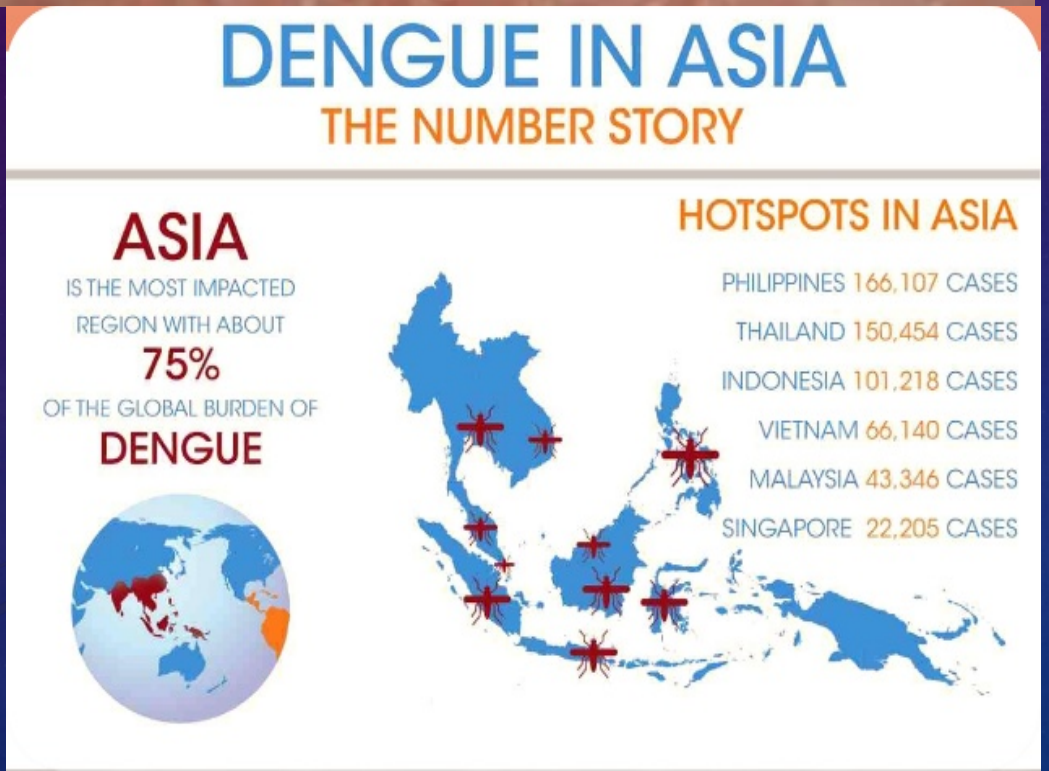
CONTROL

- Patients are asked mobility of past 2 weeks
- Based on those locations – control measures are taken

COMMON CONTROL MEASURE TAKEN IN MALAYSIA

- Fogging will be done by the Public Health personnel
- Locations identified based on patients' mobility
- Expensive – machine, experts
- Slow – only 40% houses fog within 5 days

HOW TO PRIORITIZE THE LOCATIONS?



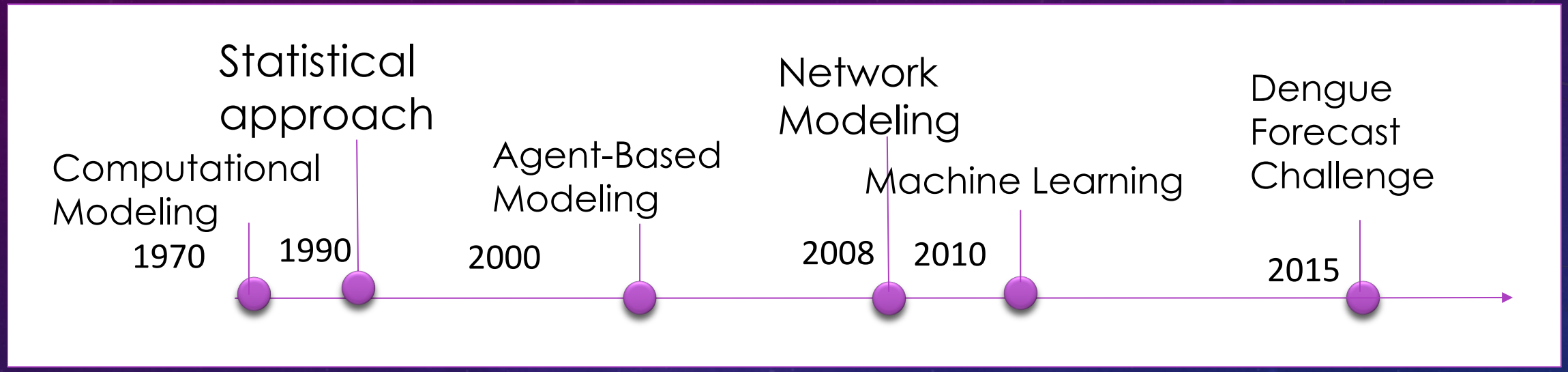
MOTIVATION

- Hotspot detection of mosquito-borne diseases for instance dengue, malaria and zika is a key to ensure the eradication (Aziz et al., 2014).
- Hotspot: is an area that has higher concentration of events compared to the expected number given a random distribution of events.
- Hotspot detection evolved from the study of point distributions or spatial arrangements of points in a space (Chakravorty, 1995).

Introduction

- HOTSPOT - prime location of mosquito breeding site.
- Main control strategy to eradicate dengue is to kill the vector mosquitoes in Malaysia (Packierisamy, 2015).
- It is important to identify and eliminate the area where it is likely a mosquito breeding site.

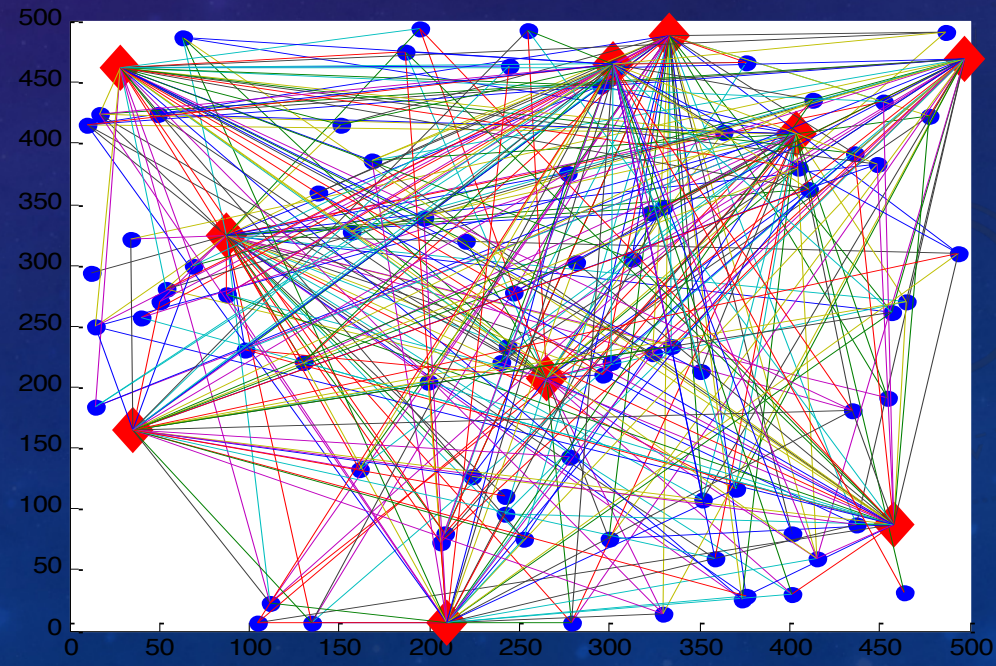
Background Of Study



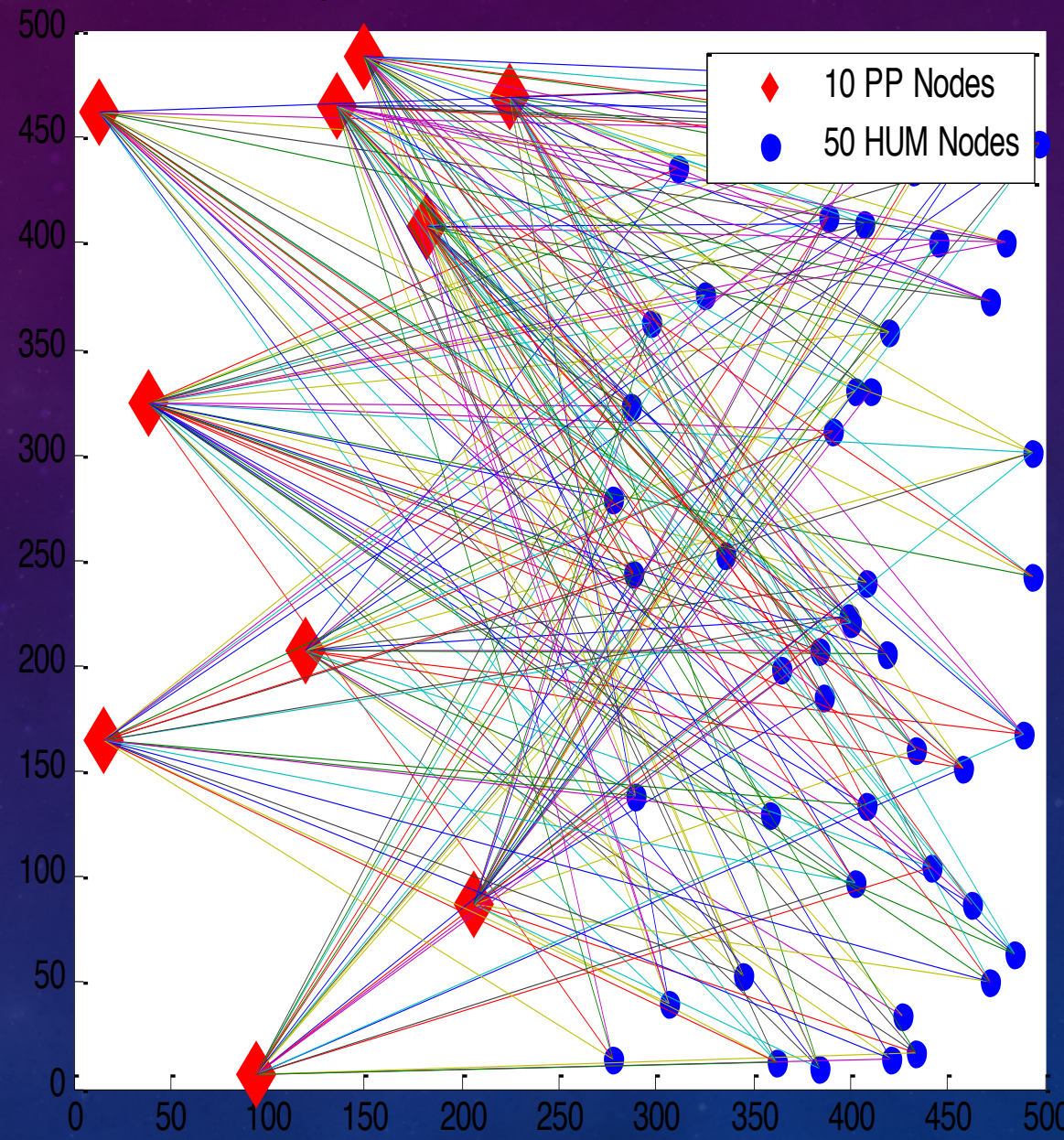
- Do not support the human mobility

OUR SOLUTION – BIPARTITE NETWORK MODELING

- Develop network of patients and locations
- Rank the locations based on patients' exposure to the disease
  - Frequencies to locations
  - Location's potentials – elevation, near river, surface temperature
- Identifying Hotspots



A SAMPLE 10P x 50H CONTACT NETWORK

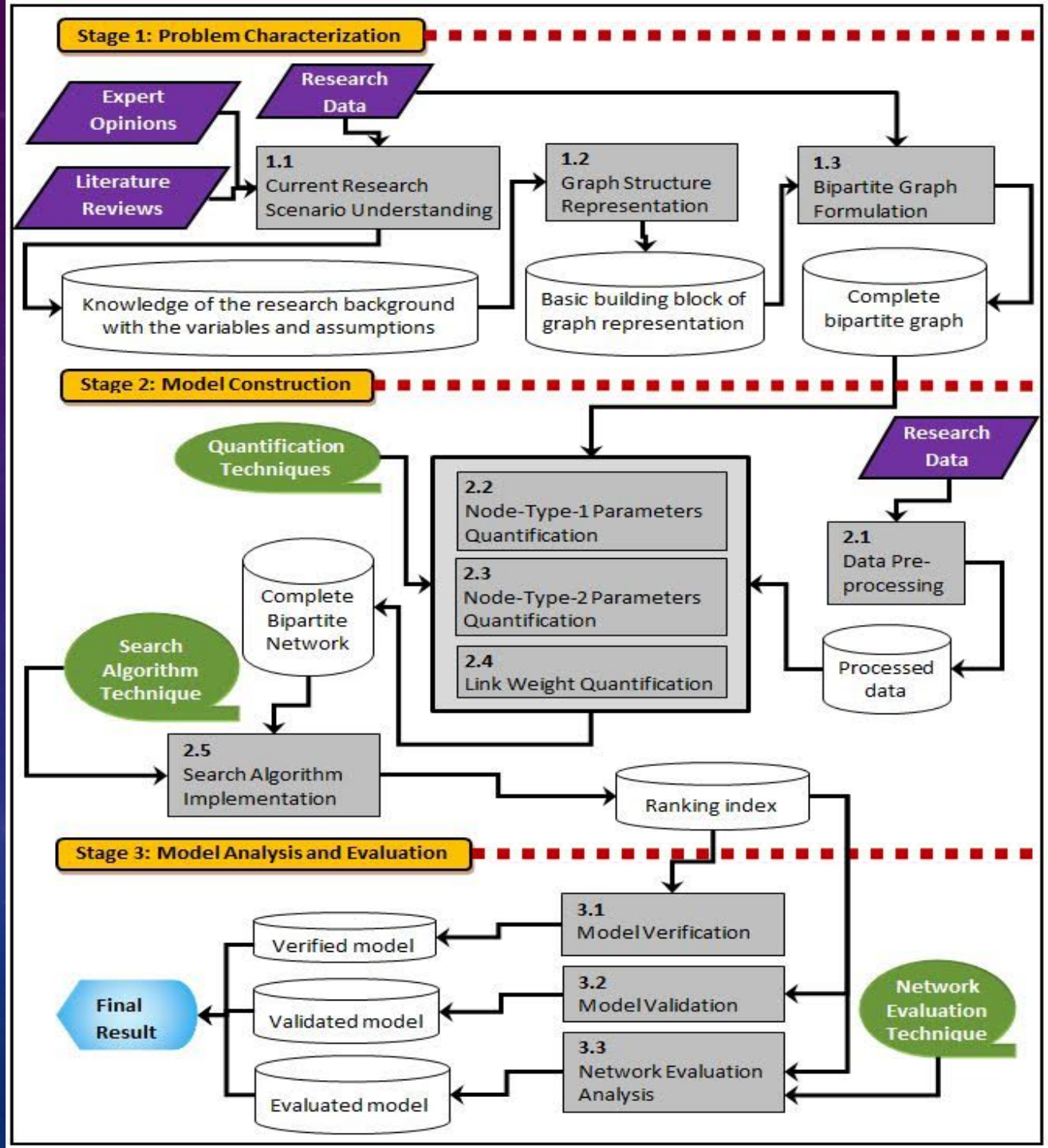

Sample M-Heterogenous Network. Generated in UNIMAS on July 6,2011
10 PP Nodes
50 HUM Nodes
0
50
100
150
200
250
300
350
400
450
500

Our Solution

- Malaria (Eze, 2013).
- Ecology – Habitat for Irrawaddy Dolphins (Liew, 2016) ; Habitat for Seagrass (Labadin*,2019)
- Dengue (Kok, 2018)

Bipartite Network Modeling Research Methodology Framework (BNM-RMF)

Liew (2016)



Dengue Research Scenario

- Data Is Scarce
- Without Physical Law To Base
- Incorporate Spatial Data

Two Components

- Host
- Visited location

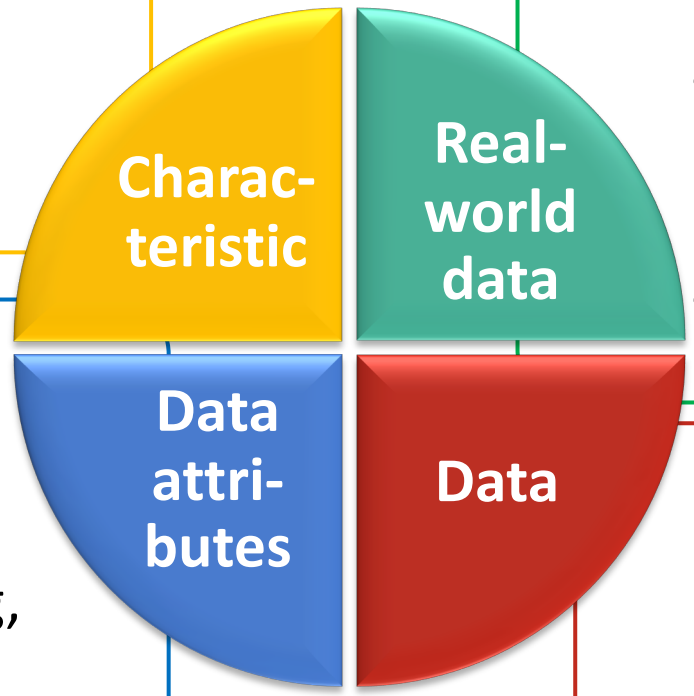
Research Question

How do we formulate two components – host and visited location – into a network model?

RESEARCH DATA(1)

- Scarce
- Discrete
- Binary

- Human (Frequency, total duration)
- Weather (temperature, precipitation and humidity)
- Location condition (Lat, Long, altitude, frequency and distance)



- Investigation form (Public Health Kuching Division)
- Environmental data (Sarawak Meteorological Office)
- July 2015 – Oct 2015 (EW 28 until EW 39)

Raw data (4 sub-dataset)

a. Epidemiological
b. Location
c. Weather
d. Mosquito

NO. KES eDENGUE :

PBV (DD/DDB/JE/CHIKU) 301
Pindaan 4/13

NOTA PEMBERITAHUAN KES
DF / DHF / DSS / SEVERE DENGUE

1) Kedudukan Kes

Kes Sporadik	WB	WT	WTK

(Pilih yang Berkenaan)

DAERAH : Kota Samarahan Bil. Minggu Epid : 30

2) Jika kes berada dalam **Lokaliti Wabak**, nyatakan nama lokaliti wabak : TB

3) Nyatakan juga **Kes Pertama** dalam lokaliti wabak yang tersebut di atas : TB

MAKLUMAT PESAKIT

4) Nama Pesakit : Ally Lim

5) Bangsa : Cina 6) Warganegara / ~~Bukan warganegara~~ : MALAYSIA

7) Umur : 33 tahun 8) Jantina : Perempuan

9) No. K/P : 10) Pekerjaan : Pensyarah

11a) Jenis K/P : / Sendiri Pengiring 11b) Nama Pengiring :

12a) Alamat **Tempat Tinggal Semasa** : One Residency Courtyard, Batu Kawa New Township, 93250

12b) Bandar / Luar Bandar

Koordinat GPS Latitude: --- Longitude: ---

12c) No. Telefon : 12d) No. H/P : 010-1234567

13a) Alamat **Lain / Tempat Kerja / Tadika / Sekolah / Kolej / Universiti** : Kolej IKMAS

13b) Bandar / Luar Bandar

Koordinat GPS Latitude: --- Longitude: ---

13c) No. Telefon : ---

MAKLUMAT NOTOFIKASI

14) Nama Klinik / Hospital yang melaporkan notifikasi ini : Sarawak General Hospital

15) Nama wad : --- 16) No. Pendaftaran :

17) Diagnosa Dalam Notifikasi Kes : DF / ~~DHF / DSS / SEVERE DENGUE~~

RESEARCH DATA (2)

- PBV (DD/DDB/JE/CHIKU) 301 Pindaan 4/13 : Investigation form used by the assistant environmental health officer with grade U29.

18) Tarikh Onset : 29/7/2016
19) Tarikh Masuk : 1/8/2016
20) Tarikh Diagnosa : 1/8/2016
21) Tarikh Notifikasi : 1/8/2016
22) Tarikh Ujian Serologi : 1/8/2016
23) Keputusan serologi : NS1: VE IGM: VE IGG: VE

24) **Tanda-tanda Klinikal** (√) pada yang berkenaan

√	Fever		Headache		Retroorbital Pain
√	Joint Pain		Myalgia/Muscle Ache		Backache
	Vomiting		Gum Bleeding		Rash
	Nose Bleeding		Ecchymosis		Petechiae
	Altered Conciousness		Purpura		Leukopenia
	Haemetesis		Nauseated		Malaena
	Fit				

Hess's Test :

25) **Warning Signs** (√) pada yang berkenaan

	Mucosal Bleed	Abdominal Pain/Tenderness
	Enlarged Liver (>2cm)	Clinical Fluid Accumulation
	Persistent Vomiting	Lethargy/Restless

26) **Tanda-tanda Klinikal Lain** *(√ pada yang berkenaan)*

	Epidemiological Link

PCV/Hematocrit :
WBC :
Platelet Count :
HB :

27) Adakah kes ini memenuhi kriteria definisi Kes Denggi? Ya / ~~Tidak~~

Jika **TIDAK**, nyatakan sebab kes ini dinotifikasikan sebagai kes denggi :

28) Nama Pegawai yang mendiagnos kes ini : Encik Abu bin Ali
28) Nama Pegawai yang melaporkan notifikasi ini : Cik Malanie Anak Juli

MAKLUMAT KLINIK PRIMER

29a) Nama Klinik Primer yang dilawati oleh pesakit sebelum notifikasi ini (jika ada) :
(definisi Klinik Primer - OPD, KK, Poliklinik, Klinik Swasta, A&E Hospital, tempat pesakit menerima rawatan OPD sahaja)

29b) Tarikh melawat Klinik Primer oleh pesakit :

29c) Diagnosa oleh Klinik Primer yang dilawati oleh pesakit : (DF) / DHS / DSS / Severe Dengue / TRO Dengue / Lain

29d) Tanda klinikal semasa pesakit melawat Klinik Primer :

29e) Jika diagnosa ialah Denggi, adakah **Rekod Pemantauan Pesakit Denggi** diberi? :

29f) Adakah notifikasi dibuat oleh Klinik Primer yang dilawati oleh pesakit? :

RUJUKAN

30a) Adakah kes ini merupakan kes yang dirujuk oleh mana-mana pihak? :

30b) Jika dirujuk, namakan institusi yang merujuk kes ini : TB

30c) Tarikh kes dirujuk : TB 30d) Diagnosa semasa dirujuk : TB

31) ***Pergerakan Pesakit - Sila lampirkan Carta Pergerakan Pesakit secara berasingan.***

32a) Nama Pegawai yang menerima notifikasi :
32b) Tarikh Menerima :

33a) Nama Pegawai yang menyiasat :
33b) Tarikh Menyiasat :

34a) Nama pegawai yang melapor :
34b) Tarikh Melapor :

RESEARCH DATA (3)

Positive or negative dengue serological result

RESEARCH DATA (4)

Human 1

Location 1

Duration: 9am until 12:30pm (3.5 hours)

CARTA PERGERAKAN PESAKIT

(Untuk dikepilkan bersama dengan Nota Pemberitahuan Kes DF / DHF / DSS / SEVERE DF)

Nama Pesakit: Ally Lim

TEMPAT	HARI	TARIKH	AKTIVITI DIJALANKAN	TEMPOH HARI DARI ONSET
Tadika Eduland, IKMAS, Rumah	Jumaat	15/7	Betolak dari rumah hantar anak ke Tadika Eduland pada 7:30 pagi. Pergi IKMAS dari jam 9 hingga 12.30 tengahari dan dari 7:30 malam hingga 9:30 malam, makan tengahari di rumah	-14
Emart Batu Kawa, rumah	Sabtu	16/7	Pergi Emart Batu Kawa jam 4pm hingga 6pm, masa lain berada dalam rumah	
Samariang	Ahad	17/7	Pergi Samariang dari jam 5 hingga 6:30pm	
Tadika Eduland, IKMAS, Rumah	Isnin	18/7	Betolak dari rumah hantar anak ke Tadika Eduland, Jalan Green 7:30 pagi. Pergi IKMAS dari jam 9 hingga 12.30 tengahari dan dari 7:30 malam hingga 9:30 malam, makan tengahari di rumah	-11
Tadika Eduland, IKMAS, Rumah, Plaza Merdeka	Selasa	19/7	Betolak dari rumah hantar anak ke Tadika Eduland, Jalan Green 7:30 pagi. Pergi IKMAS dari jam 9 hingga 12.30 tengahari dan dari 7:30 malam hingga 9:30 malam, makan tengahari di Plaza Merdeka dari 2pm hingga 4pm.	-10
Tadika Eduland, IKMAS, Rumah	Rabu	20/7	Betolak dari rumah hantar anak ke Tadika Eduland, Jalan Green 7:30 pagi. Pergi IKMAS dari jam 9 hingga 12.30 tengahari dan dari 7:30 malam hingga 9:30 malam, makan tengahari di rumah	-9
Tadika Eduland, IKMAS, Rumah	Khamis	21/7	Betolak dari rumah hantar anak ke Tadika Eduland, Jalan Green 7:30 pagi. Pergi IKMAS dari jam 9 hingga 12.30 tengahari dan dari 7:30 malam hingga 9:30 malam, makan tengahari di rumah	
Tadika Eduland, IKMAS, Rumah	Jumaat	22/7	Betolak dari rumah hantar anak ke Tadika Eduland, Jalan Green 7:30 pagi. Pergi IKMAS dari jam 9 hingga 12.30 tengahari dan dari 7:30 malam hingga 9:30 malam, makan tengahari di rumah	-7
Rumah	Sabtu	23/7	Berada dalam rumah	-6
Pasar Batu 3, rumah	Ahad	24/7	Pergi pasar batu 3 masa 8 pagi hingga 10pagi. Masa lain berada dalam rumah sahaja.	-5
Tadika Eduland, IKMAS, Rumah	Isnin	25/7	Betolak dari rumah hantar anak ke Tadika Eduland, Jalan Green 7:30 pagi. Pergi IKMAS dari jam 9 hingga 12.30 tengahari dan dari 7:30 malam hingga 9:30 malam, makan tengahari di rumah	-4

Probable infection period

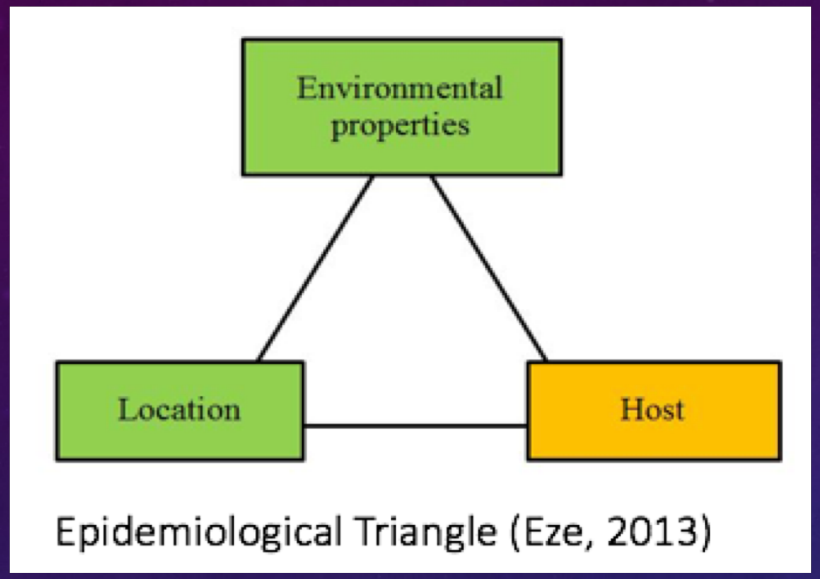
RESEARCH DATA (5)

Tadika Eduland, IKMAS, Rumah	Selasa	26/7	Betolak dari rumah hantar anak ke Tadika Eduland, Jalan Green 7:30 pagi. Pergi IKMAS dari jam 9 hingga 12.30 tengahari dan dari 7:30 malam hingga 9:30 malam, makan tengahari di rumah	-3
Tadika Eduland, IKMAS, Rumah	Rabu	27/7	Betolak dari rumah hantar anak ke Tadika Eduland, Jalan Green 7:30 pagi. Pergi IKMAS dari jam 9 hingga 12.30 tengahari dan dari 7:30 malam hingga 9:30 malam, makan tengahari di rumah	-2
Tadika Eduland, IKMAS, Rumah	Khamis	28/7	Betolak dari rumah hantar anak ke Tadika Eduland, Jalan Green 7:30 pagi. Pergi IKMAS dari jam 9 hingga 12.30 tengahari dan dari 7:30 malam hingga 9:30 malam, makan tengahari di rumah	-1
Rumah	Jumaat	29/7	Ada demam dan pening kepala, ambil cuti dan berada di rumah sahaja	ONSET
			Jumpa doctor dalam hospital	1
				2
				3
				4
				Lawatan ke Klinik Primer(jika ada)
				Diagnosas
				Notifikasi (jika ada)
				Kemasukan Hospital (Jika ada)
				Diagnosa
				Notifikasi (Jika ada)
				DIrujuk (Jika Ada)
				Siasatan

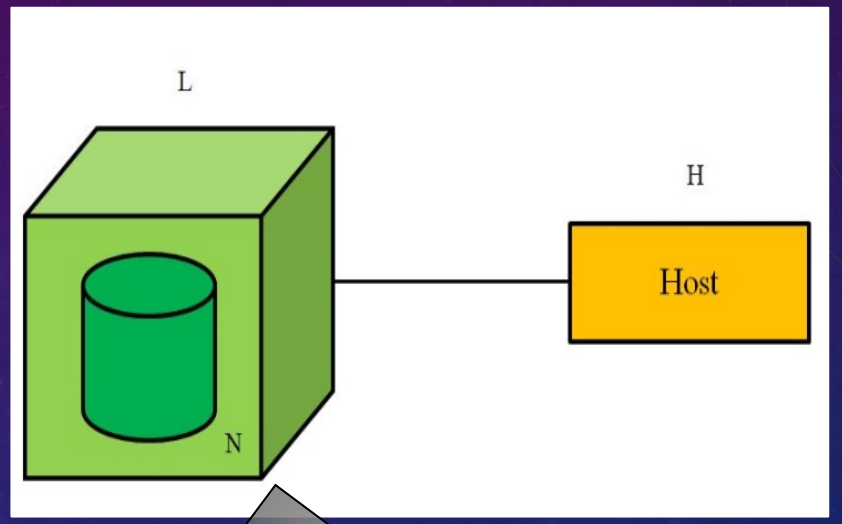
Viremia period

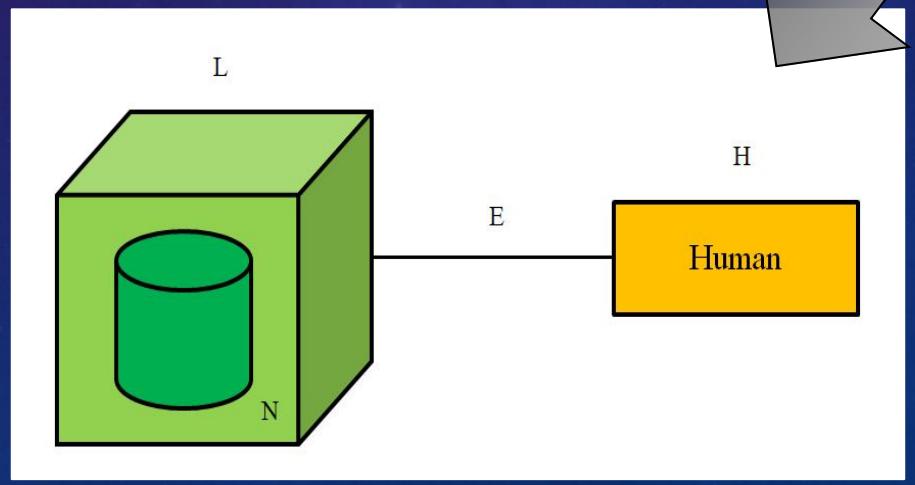
Viremia period

Formalization Of Bipartite Graph



Epidemiological Triangle (Eze, 2013)





Group	BDC Network Model	Model	Epi Week	Number of Human Nodes	Number of Location Nodes
1	1	Targeted model 1	28-29	2 patients with positive dengue test 6 patients with negative dengue test	19 locations
	2	Validated model 1	30-31	3 patients with positive dengue test only	27 locations with 8 new locations
2	3	Targeted model 2	32-33	9 patients with positive dengue test 3 patients with negative dengue test	78 locations with 51 new locations
	4	Validated model 2	34-35	2 patients with positive dengue test only	81 locations with 3 new locations
3	5	Targeted model 3	36-37	3 patients with positive dengue test 7 patients with negative dengue test	98 locations with 17 new locations
	6	Validated model 3	38-39	7 patients with positive dengue test only	100 locations with 2 new locations

Identification of Bipartite Dengue Contact (BDC) Network

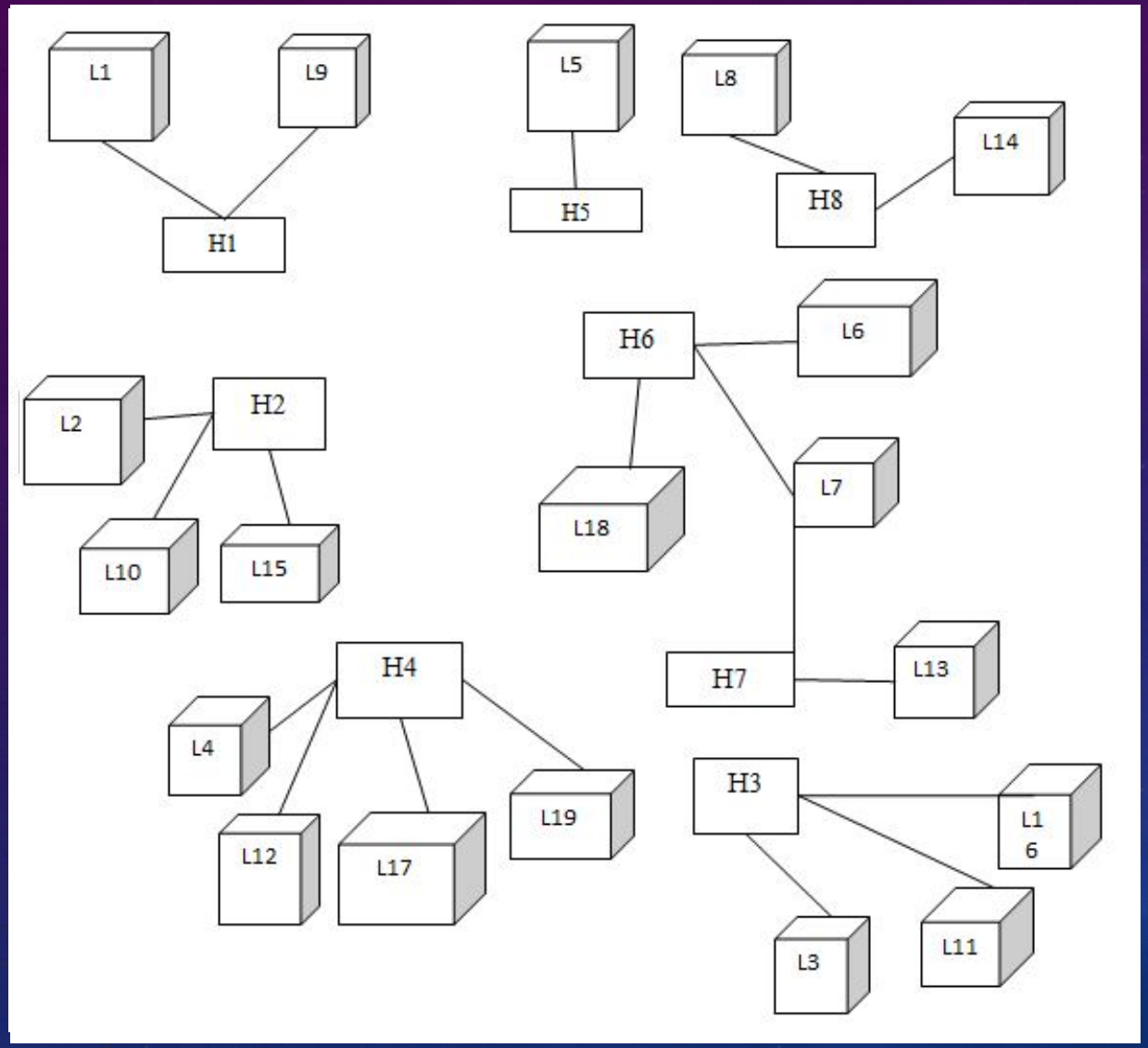
- 2 Epid Week (EW) data used to formulate 1 network
- In Targeted Model: patient with positive and negative results of serological test
- To formulate possible vector location and detect the possible hotspot

H node labelled	Date	L node visited
H1	25-Jun-15	L1
	25-Jun-15	L9
H2	30-Jun-15	L2
	30-Jun-15	L10
	30-Jun-15	L15
H3	1-Jun-15	L3
	1-Jul-15	L11
	17-Jun-15	L16
H4	15-Jun-15	L4
	20-Jun-15	L12
	23-Jun-15	L17
	27-Jun-15	L19
H5	8- Jul-15	L5
H6	8- Jul-15	L6
	23-Jun-15	L7
	3- Jul-15	L18
H7	9-Jul-15	L7
	25-Jun-15	L13
H8	6-Jul-15	L8
	22-Jun-15	L14

Human Mobility in the First Network

- Identification of human nodes
- Identification of location nodes
- Identification of link between nodes

Formalization of Bipartite Graph (2)



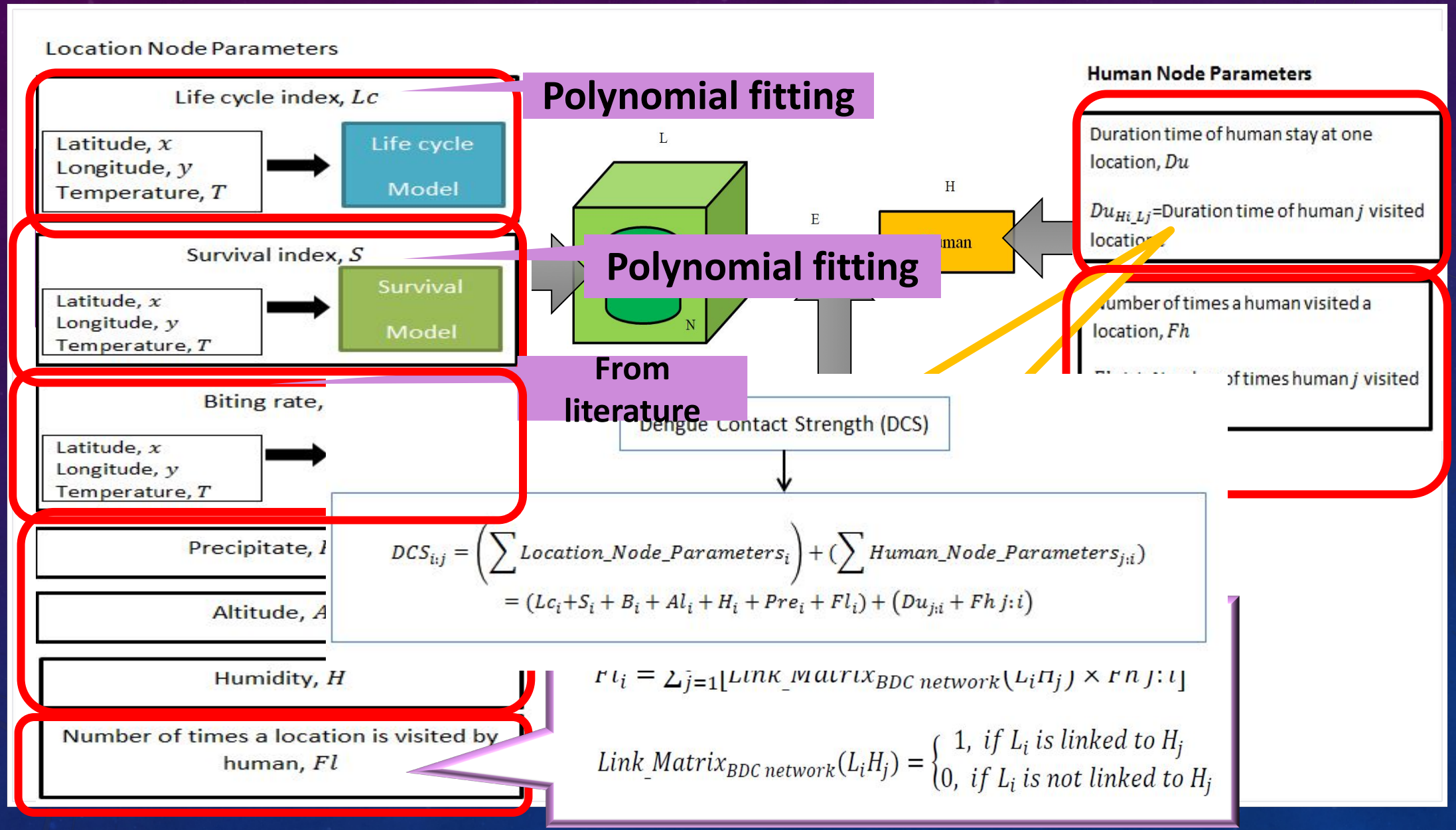
BDC_{DEN_KCH} = BDC(H, L, E)

H = {H1, H2, H3, H4, H5, H6, H7, H8}

L= {L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11, L12, L13, L14, L15, L16, L17, L18, L19}

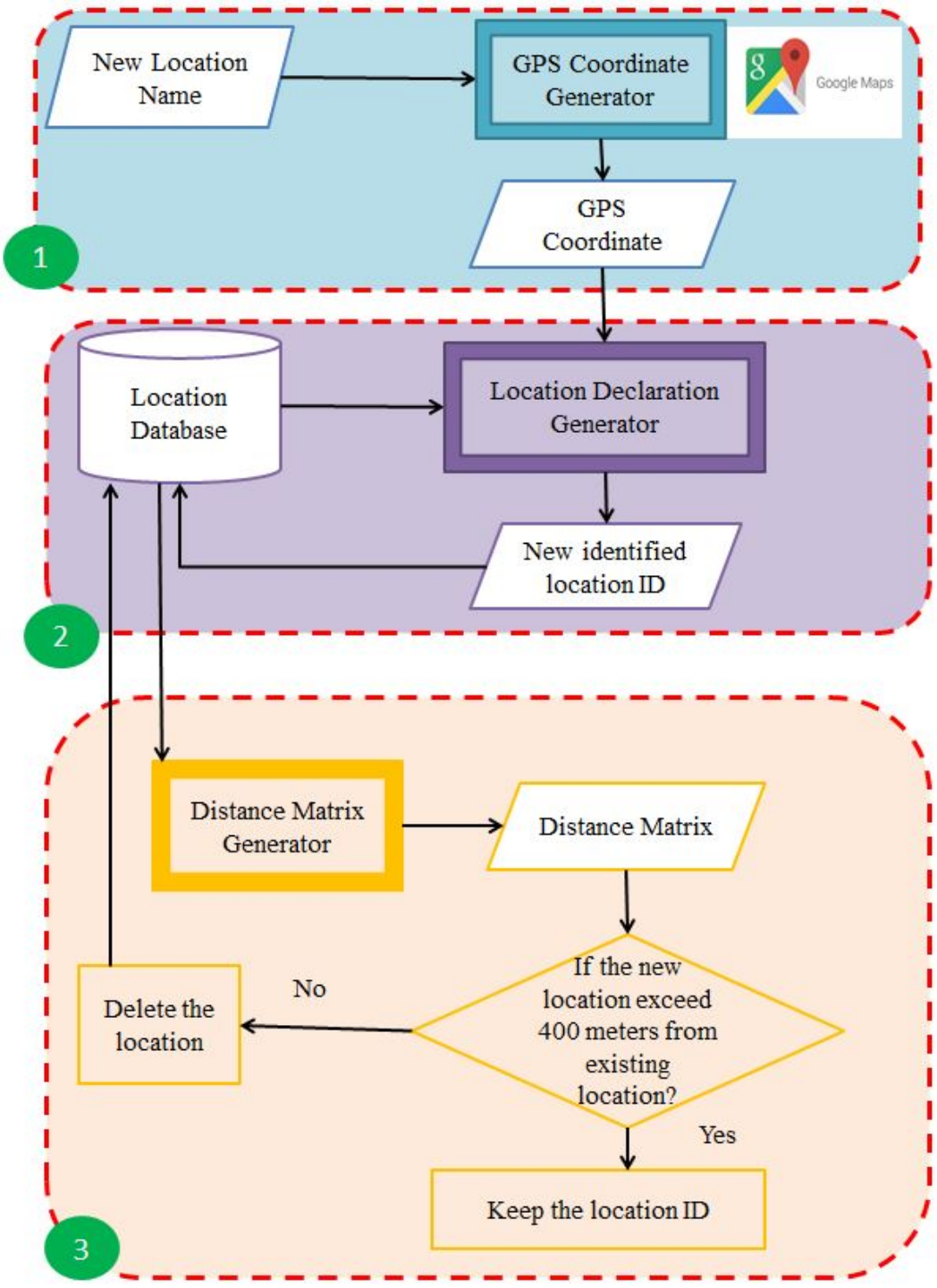
E = {H1L3, H1L9, H2L10, H2L15, H3L3, H3L3, H3L11, H3L16, H4L4, H4L12, H4L17, H4L19, H5L5,H6L6, H6L7, H6L18, H7L7, H7L13, H8L8, H8L14}

Bipartite Network Formulation



Data pre-processing

- Pre-process of data used for:
  a) Location
  b) Human
  c) Link between location and human

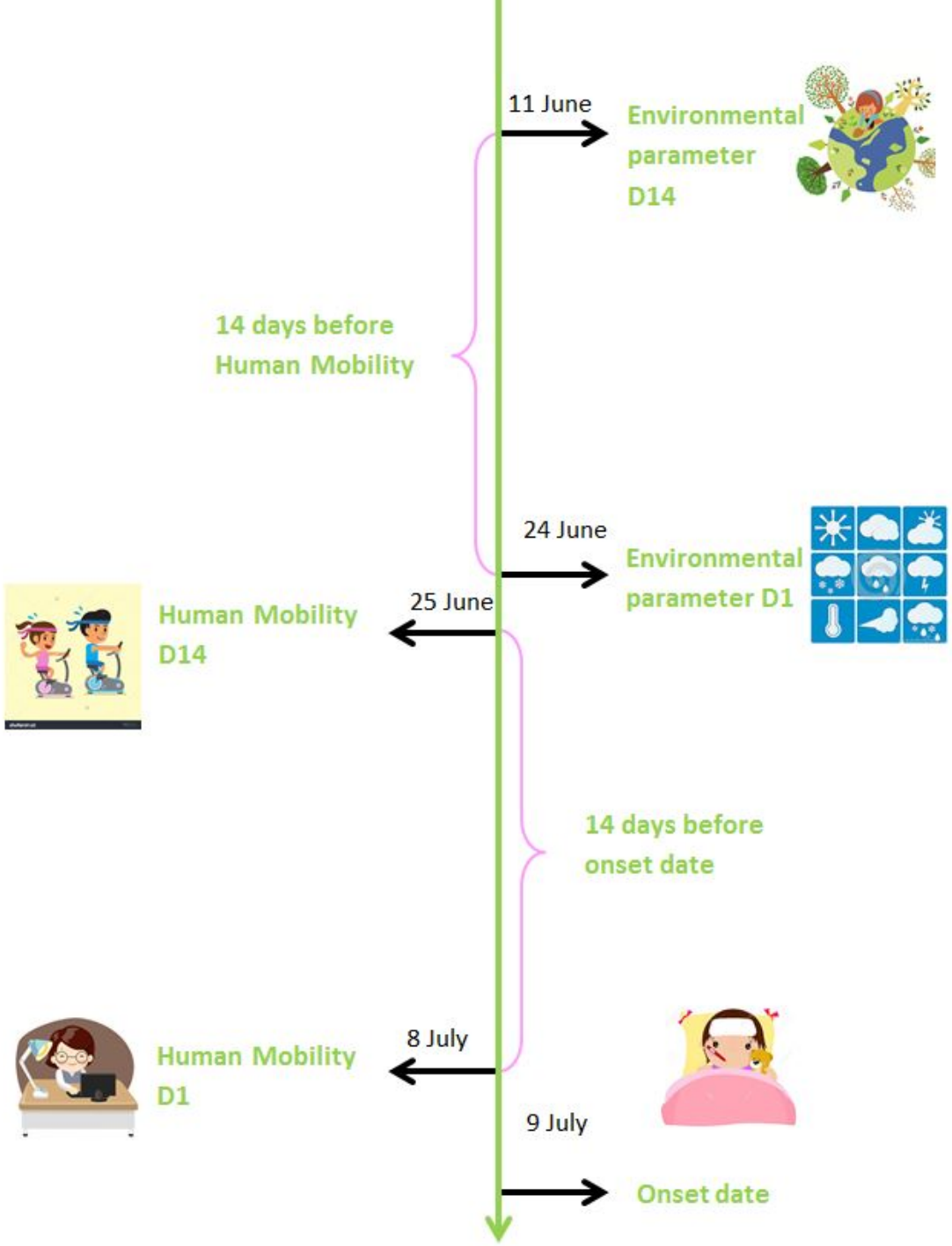


Pre-processing of location node

- Aim 1: Generate the GPS coordinate pairs ie. Latitude and Longitude
- Aim 2: Calculate the distance between the identified location node
- 2 functions are implemented by using R Software: Location Declaration Generator and Distance Matric Generator
- Output: A distance matrix that consists of all distances between the location node.
- The location node in database is 400 meters away from another location node

Pre-processing of Human node

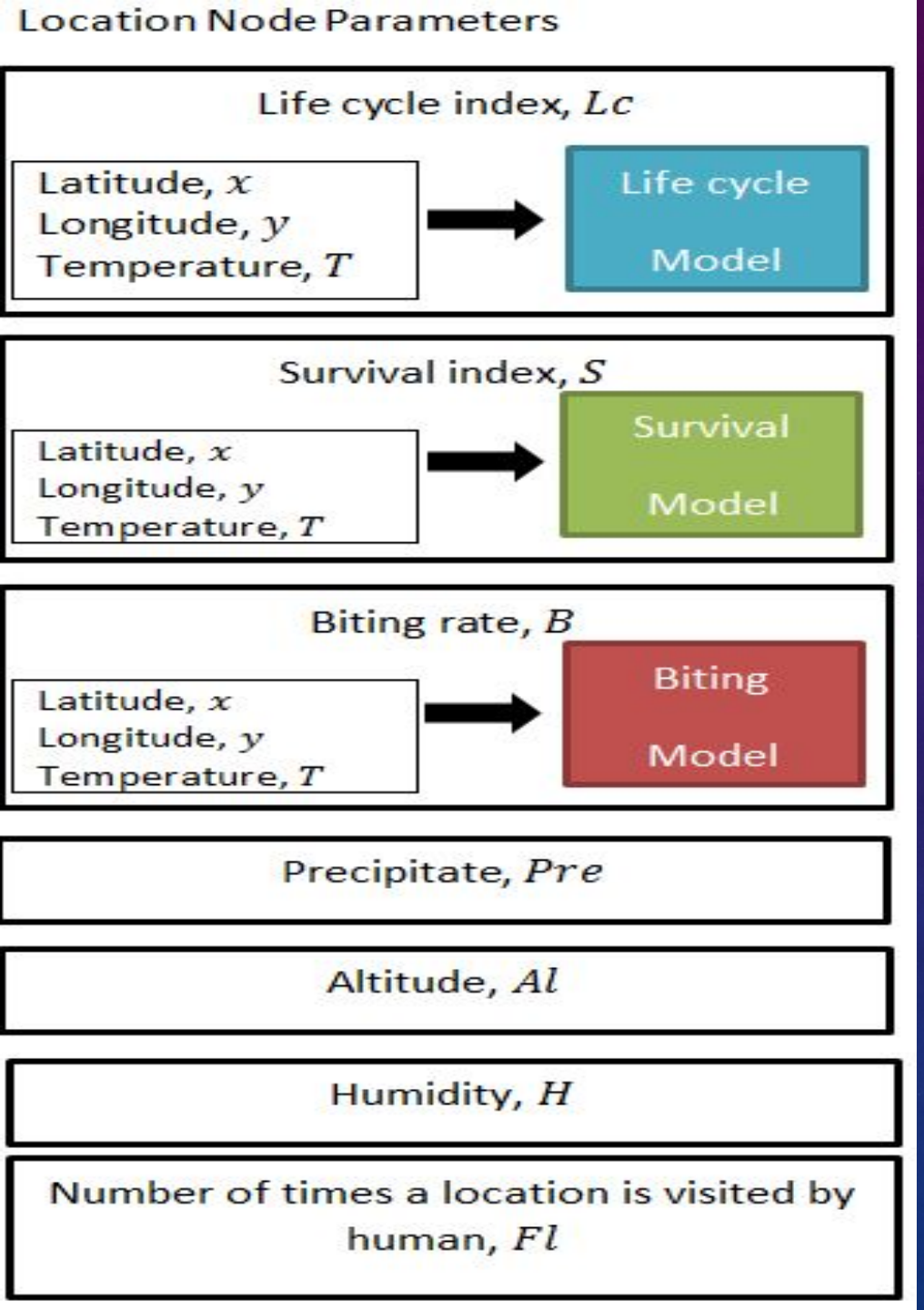
- To protect the patient confidentiality, patient identity is replaced with an algorithm-generated ID.
- For instance, the human nodes in the first Bipartite Dengue Contact Network consists of 8 human nodes.
- Thus, the identified nodes are H1, H2, H3, …, H7 and H8.



Pre-processing of Parameter

- Parameters: temperature, humidity, precipitation and altitude
- Since human mobility data capture the patients' movement 2 weeks before the onset date, in order to observe the effect of the environmental parameter, average of the parameter values among these 2 weeks before need to be calculated.

Quantification of Location Node Parameter



- Life cycle model
- Survival model
- Vector biting model

Vector Life Cycle Duration, *Lc*

- Life cycle duration: measures the duration of development from mosquito egg hatching to adult
- However, no direct life cycle duration data has been published.
- The life cycle could naturally be implied by the attributes of a location node and the environmental properties enclosed.
- Thus, these attributes that are reflected through the location physical characteristic and condition can be utilized to imply the life cycle duration of the mosquitoes at one locality.

Vector Life Cycle Duration, *Lc* (2)

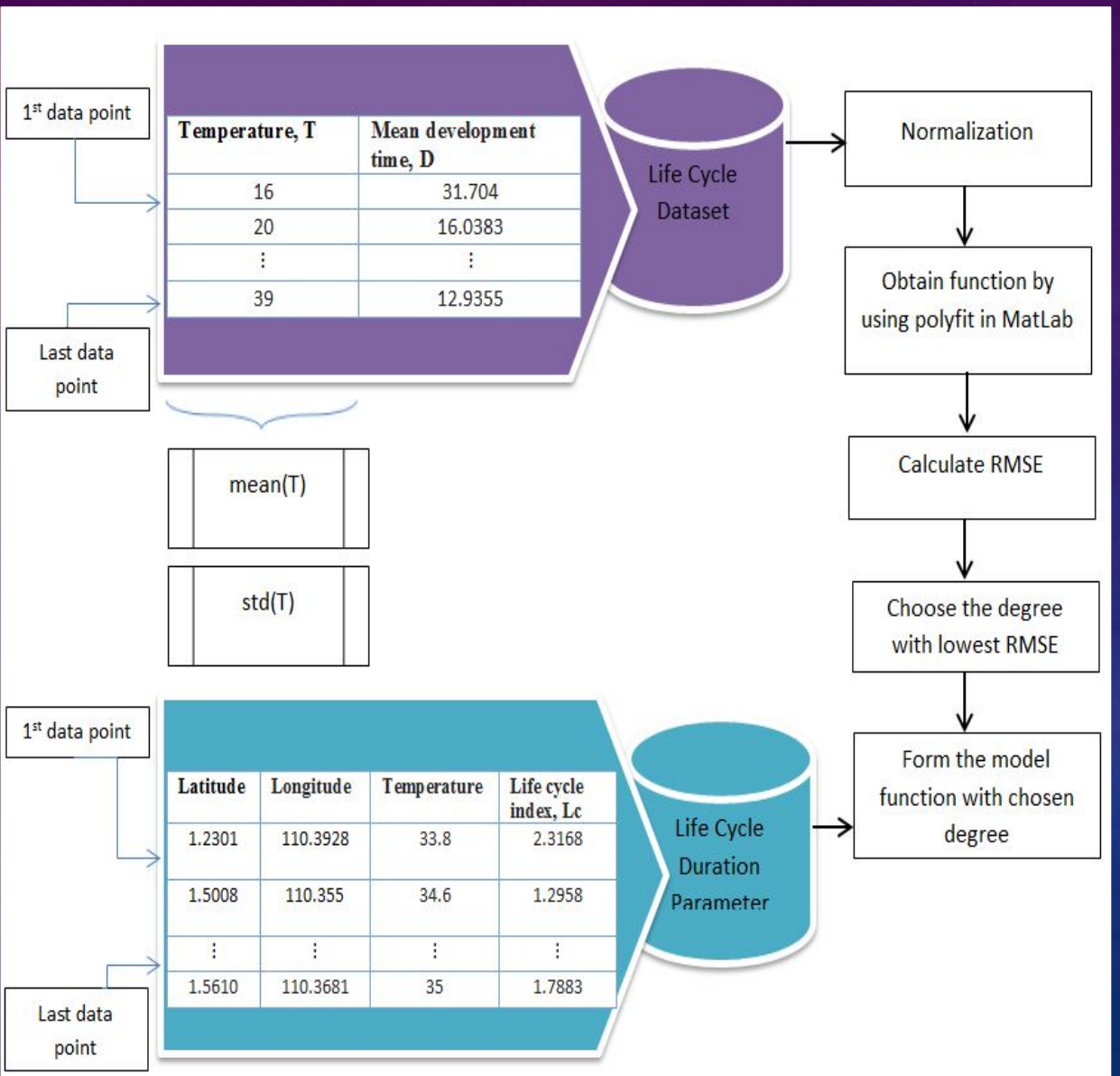
Temperature, T (℃)	Mean development time from egg hatching to pupation, D (days)
16	31.704
20	16.0383
26	9.15326
30	6.45608
35	5.85143
37	7.79076
38	7.75892
39	12.9355

Experimental research data

- Mosquito: Female Aedes Aegypti collected from Kamphaeng Phet, Thailand
- Collected from field: Jan 2011
- Eggs were hatched in water using a vacuum manifold and reared under a controlled density (<200 larvae per tray) in containers (<3362966 cm) with 1.5L of deionized water
- Larvae were fed as previously described in Styer et al (2007)

(Carrington et al., 2013)

Vector Life Cycle Duration, *Lc* (3)



- Life cycle duration: polynomial function of the temperature attribute at particular locality
- Polynomial fitting: polyfit tool in MatLab

Degree	RMSE
1	3.2174
2	0.8218
3	0.5501
4	0.2547
5	0.1290
6	3.44×10^{-15}
7	4.11×10^{-15}

$$Lc(t) = -0.633t^6 - 0.786t^5 + 1.488t^4 + 1.153t^3 - 0.408t^2 - 0.758t - 0.504$$

Vector Life Cycle Duration, *Lc* (4)

Latitude, Longitude	L node	Visited by	Temp(℃)	Lc(days)	$\frac{1}{Lc}$
1.2301, 110.3928	L1	H1	33.8	5.0134	0.1995
1.5008, 110.3550	L2	H2	34.6	5.5030	0.1817
1.3999, 110.3251	L3	H3	32.2	4.9800	0.2000
1.5384, 110.3603	L4	H4	33.7	4.9742	0.2008
1.5363, 110.3565	L5	H5	34.7	5.5845	0.1791
1.5375, 110.3867	L6	H6	34.7	5.5845	0.1791
1.2423, 110.4951	L7	H6	33.6	4.9400	0.2024
		H7	34.4	5.3528	0.1868
1.5473, 110.3604	L8	H8	35	5.8514	0.1709
1.2853, 110.2814	L9	H1	33.8	5.0134	0.1995
1.2365, 110.2718	L10	H2	34.6	5.5030	0.1817
1.6118, 110.2258	L11	H3	32.5	4.8942	0.2043
1.6102, 110.3351	L12	H4	33.9	5.0578	0.1977
1.5006, 110.3504	L13	H7	33.8	5.0134	0.1994
1.6362, 110.3384	L14	H8	33.7	4.9742	0.2010
1.5350, 110.3373	L15	H2	34.6	5.5030	0.1817
1.4288, 110.3280	L16	H3	32.5	4.8942	0.2043
1.6338, 110.3311	L17	H4	33.7	4.9742	0.2010
1.5567, 110.2475	L18	H6	34.7	5.5845	0.1791
1.5610, 110.3681	L19	H4	33.9	5.0578	0.1977

- To substitute the temperature of the first BDC network into the life cycle duration function
- Life cycle duration is inversely proportional to the vector density at one locality.
- The shorter the time taken for a complete life cycle leads to a shorter time the vector density increase.

Vector Survival Parameter, *S*

- Survival parameter: measures the survival probability at a locality as an indication of vector survival rate at one locality.
- However, no direct vector survival data has been published.
- Similarly, the vector survival could naturally be implied by the attributes of a location node and the environmental properties enclosed.

Vector Survival Parameter, *S* (2)

Temperature, T (℃)	Vector Survival, Sv (%)
10	0
15	23.5
20	90
25	88
27	93
30	88
34	67

Experimental research data

- Mosquito: Female Aedes Aegypti collected from Thailand
- Collected from field: 1999

(Tun-Lin, Burkot & Kay, 2000)

Vector Survival, S (3)

- Vector Survival: polynomial function of the temperature attribute at particular locality
- Polynomial fitting: polyfit tool in MatLab

Degree	RMSE
1	0.6051
2	0.2610
3	0.2366
4	0.1752
5	0.0602
6	3.1264×10^{-15}

$$S(t) = 1.3908t^6 - 0.2951t^5 - 3.8642t^4 + 1.3217t^3 + 1.2971t^2 - 0.1412t + 0.591$$

Vector Survival Rate, *S* (4)

Latitude, Longitude	L node	Visited by	Temp(℃)	*S* (%)
1.2301, 110.3928	L1	H1	33.8	65.1060
1.5008, 110.3550	L2	H2	34.6	78.1297
1.3999, 110.3251	L3	H3	32.2	68.8743
1.5384, 110.3603	L4	H4	33.7	64.4377
1.5363, 110.3565	L5	H5	34.7	80.9369
1.5375, 110.3867	L6	H6	34.7	80.9369
1.2423, 110.4951	L7	H6	33.6	63.9387
		H7	34.4	73.3948
1.5473, 110.3604	L8	H8	35	91.3251
1.2853, 110.2814	L9	H1	33.8	65.1060
1.2365, 110.2718	L10	H2	34.6	78.1297
1.6118, 110.2258	L11	H3	32.5	66.5415
1.6102, 110.3351	L12	H4	33.9	65.9558
1.5006, 110.3504	L13	H7	33.8	65.1060
1.6362, 110.3384	L14	H8	33.7	64.4377
1.5350, 110.3373	L15	H2	34.6	78.1297
1.4288, 110.3280	L16	H3	32.5	66.5415
1.6338, 110.3311	L17	H4	33.7	64.4377
1.5567, 110.2475	L18	H6	34.7	80.9369
1.5610, 110.3681	L19	H4	33.9	65.9558

- To substitute the temperature of the first BDC network into the vector survival function
- Vector survival is directly proportional to the vector density at one locality.
- The higher the vector survival rate contributes a higher vector capacity at one locality.

Vector Biting Parameter, *B*

- An increase in the vector biting rate, a higher risk level of the locality.

$$B(T) = \begin{cases} 0.004286T + 0.09429, & 21℃ \leq T \leq 32℃, \\ 0.8, & otherwise. \end{cases}$$ (Scott et al, 2012)

- Mosquito: Female Aedes Aegypti collected from south central Thailand
- Collected from field: June 1992

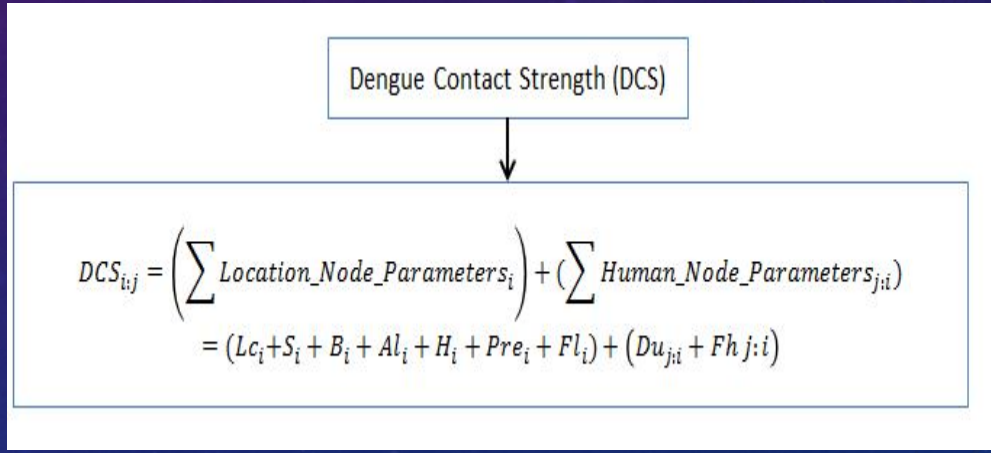
Vector Biting Parameter, *B* (2)

Latitude, Longitude	L node	Visited by	Temp(℃)	$B\ (\frac{1}{day})$
1.2301, 110.3928	L1	H1	33.8	0.8
1.5008, 110.3550	L2	H2	34.6	0.9
1.3999, 110.3251	L3	H3	32.2	0.8
1.5384, 110.3603	L4	H4	33.7	0.8
1.5363, 110.3565	L5	H5	34.7	0.8
1.5375, 110.3867	L6	H6	34.7	0.8
1.2423, 110.4951	L7	H6	33.6	0.8
		H7	34.4	0.8
1.5473, 110.3604	L8	H8	35	0.8
1.2853, 110.2814	L9	H1	33.8	0.8
1.2365, 110.2718	L10	H2	34.6	0.8
1.6118, 110.2258	L11	H3	32.5	0.8
1.6102, 110.3351	L12	H4	33.9	0.8
1.5006, 110.3504	L13	H7	33.8	0.8
1.6362, 110.3384	L14	H8	33.7	0.8
1.5350, 110.3373	L15	H2	34.6	0.8
1.4288, 110.3280	L16	H3	32.5	0.8
1.6338, 110.3311	L17	H4	33.7	0.8
1.5567, 110.2475	L18	H6	34.7	0.8
1.5610, 110.3681	L19	H4	33.9	0.8

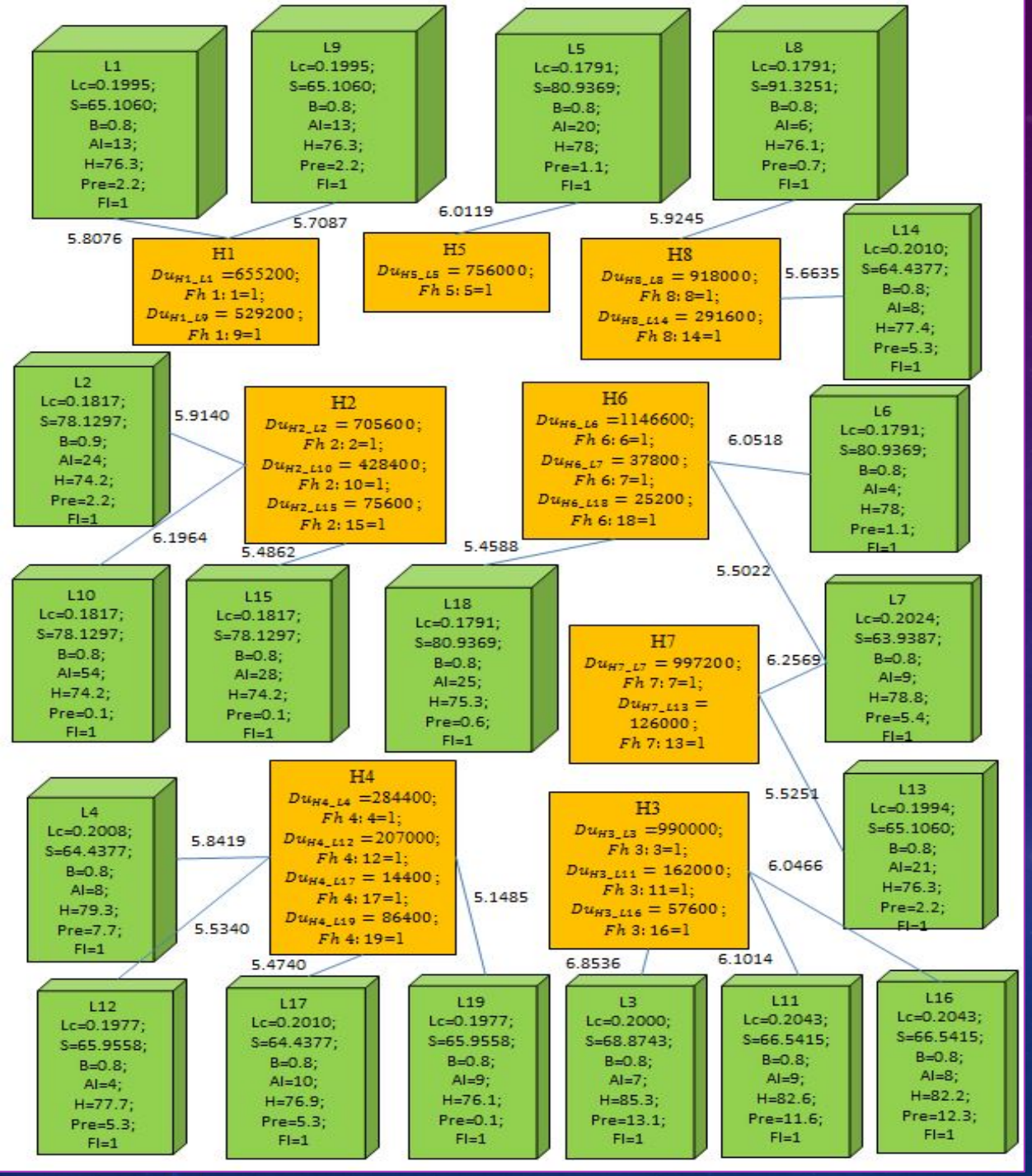
- Biting rate

Dengue Contact Strength

	H1	H2	H3	H4	H5	H6	H7	H8
L1	5.8076	0	0	0	0	0	0	0
L2	0	5.9140	0	0	0	0	0	0
L3	0	0	6.8536	0	0	0	0	0
L4	0	0	0	5.8419	0	0	0	0
L5	0	0	0	0	6.0119	0	0	0
L6	0	0	0	0	0	6.0518	0	0
L7	0	0	0	0	0	5.5022	6.2569	0
L8	0	0	0	0	0	0	0	5.9245
L9	5.7087	0	0	0	0	0	0	0
L10	0	6.1964	0	0	0	0	0	0
L11	0	0	6.1014	0	0	0	0	0
L12	0	0	0	5.5340	0	0	0	0
L13	0	0	0	0	0	0	5.5251	0
L14	0	0	0	0	0	0	0	5.6635
L15	0	5.4862	0	0	0	0	0	0
L16	0	0	6.0466	0	0	0	0	0
L17	0	0	0	5.4740	0	0	0	0
L18	0	0	0	0	0	5.4588	0	0
L19	0	0	0	5.1485	0	0	0	0

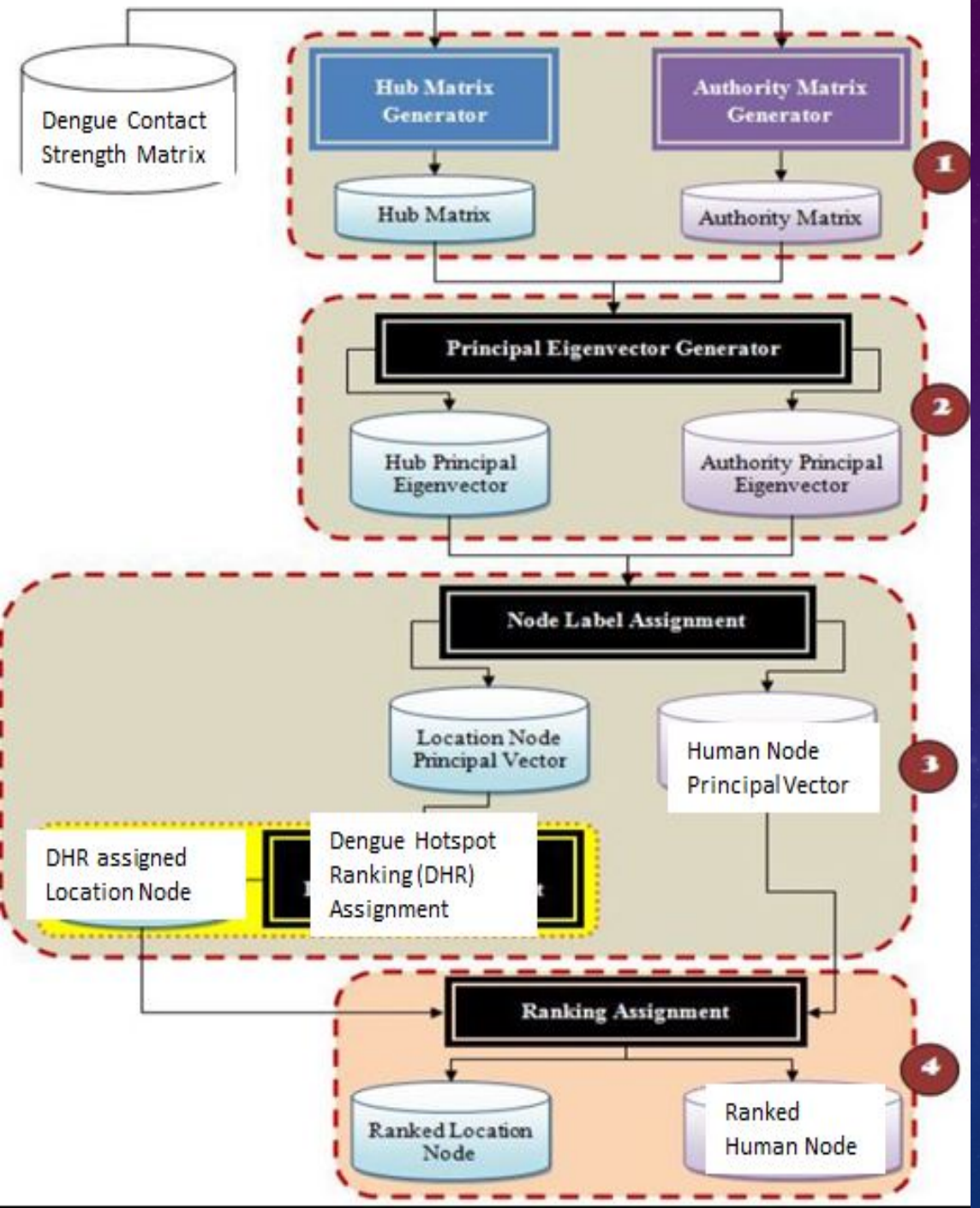


Bipartite Dengue Contact Network



- The first network model:
  1. 8 human nodes
  2. 19 location nodes
  3. 20 links

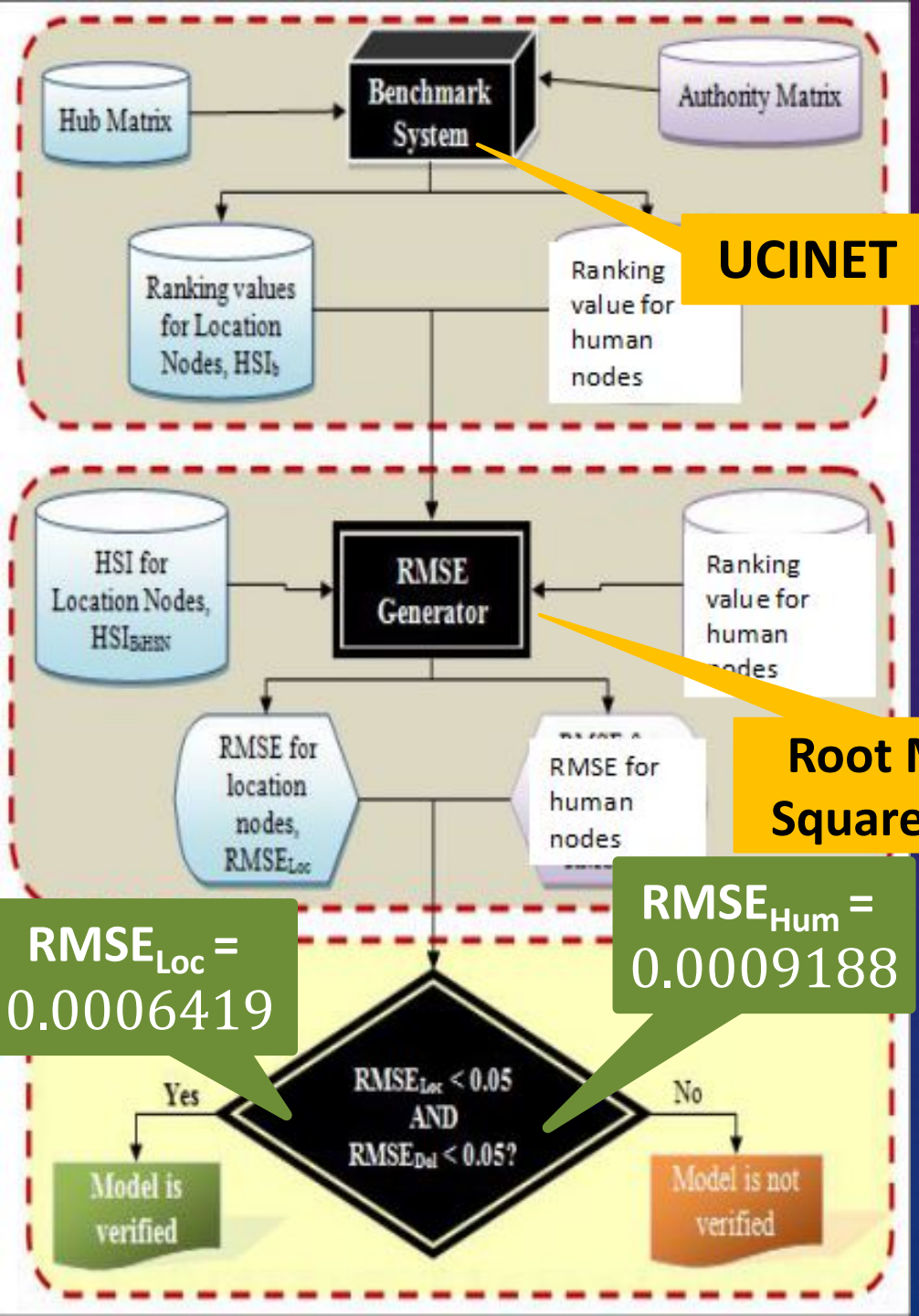
WEB-BASED SEARCH ALGORITHM



Location Node Label	DHR Value
L4	1
L12	0.947297
L17	0.937019
L19	0.881315
L3	0.001617
L11	0.00144
L16	0.001427
L7	7.49E-07
L6	4.64E-07
L18	4.19E-07
L13	2.89E-07
L10	3.3E-116
L2	3.1E-116
L15	2.9E-116
L1	0
L5	0
L8	0
L9	0
L14	0

Human Node Label	Ranking Value
H4	1
H3	0.002599
H6	1.96E-06
H7	1.34E-06
H2	2.1E-107
H1	0
H5	0
H8	0

Model Verification



- Since both RMSE is much more smaller than the threshold RMSE (0.05), the model is verified.

MODEL VALIDATION

Group	BDC Network	Model	Epi Week	SRCC Values
1	1	Targeted Model 1	28-29	1.0000
	2	Validated Model 1	30-31	
2	3	Targeted Model 2	32-33	0.8000
	4	Validated model 2	34-35	
3	5	Targeted Model 3	36-37	0.8424
	6	Validated Model 3	38-39	

- Spearman coefficient is used to measure the degree of relationship between a pair of rankings.
- Spearman's Rank Correlation Coefficient (SRCC) used in model validation in this study to measure the closeness of the ranking values between the targeted and validated models.
- The threshold value is 0.70.
- Since all 3 groups show strong positive correlation (SRCC > 0.70), hence the model is validated.

Parameter Significance Analysis

- To determine the relative importance of individual parameter included in the BDC network model.
- We identify the key parameters which have greater influences on the performance of the algorithm.

Parameters that are relatively more significant are:

1. Biting rate, *B*
2. Duration time the human stay at one location, *Du*

LIMITATIONS

- The life cycle and survival rate is derived from the experimental data obtained from published works.
- However, the mosquito collected in these studies is Aedes Aegypti, there is no another dengue vector, Aedes Albopictus.
- Since there is no data obtained for this vector, and hence this might affect the accuracy and effectiveness of the dengue network model.
- Hence, it is encouraging to have experimental data of Aedes Albopictus in term of the life cycle duration and survival rate.

Conclusion

- The General Modeling Research Community
  - Applicability of BNM approach
  - Practicality of BNM-RMF
  - Predictive nature of bipartite network model
- The Body of Knowledge of the related research fields
  - DCS
  - DHR for dengue vector at the location
  - Ranked Location nodes
  - Quantify Life Cycle Duration and Vector Survival rate
  - Parameter Significance Analysis
- The specific end-user and research communities
  - Algorithm to calculate the distance matrix
  - Assist public health in decision making

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- Postgraduate students