Chapter 8: Deployment & Data Access MAC Scheduling Protocols on VANETs

Optimal Placement of Gateways in Vehicular Networks

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Introduction

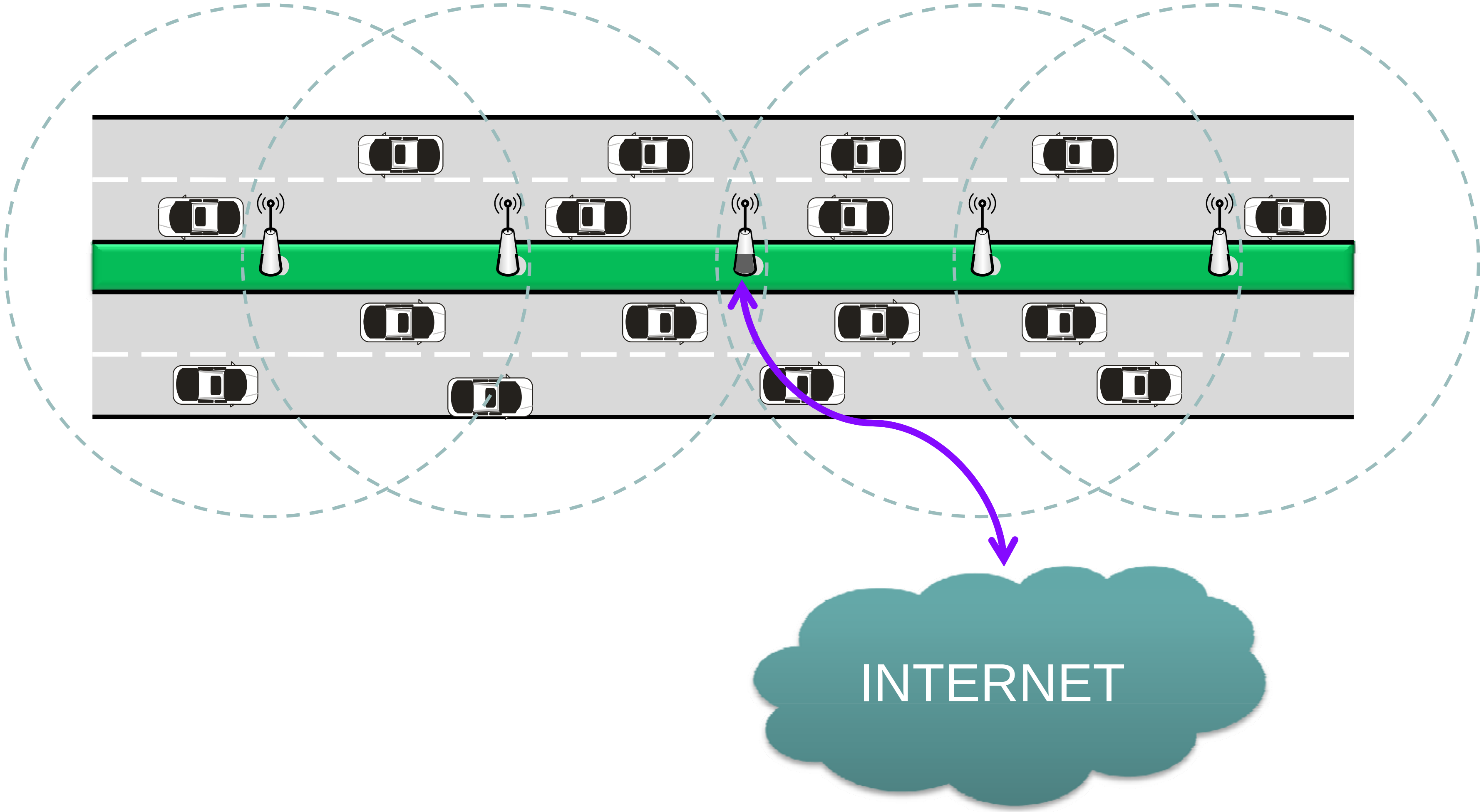
- Mobile users in vehicles require to access the Internet.
- How to place gateways to link mobile nodes to the Internet ?

Goals

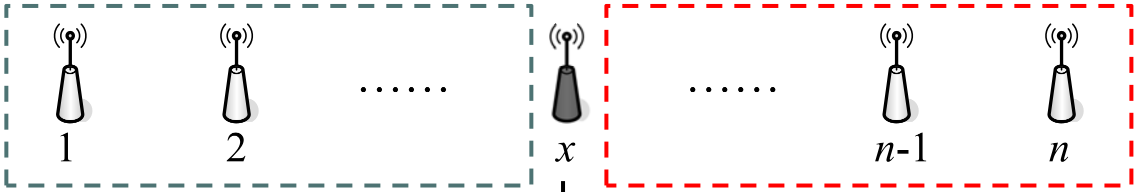
- Optimally placing gateways.
  - Minimize the average number of hops from APs to gateways.
  - Minimize the total power consumption.
  - Maximize the average capacity of each AP.

1-D Vehicular Networks

Assume that several APs have been deployed.
Which AP should play the role of gateway?



One Gateway



$$H(x)=\frac{1}{n}[(x-1)+(x-2)+\ldots+1+0+1+2+\ldots+(n-x)]$$

Average number of hops

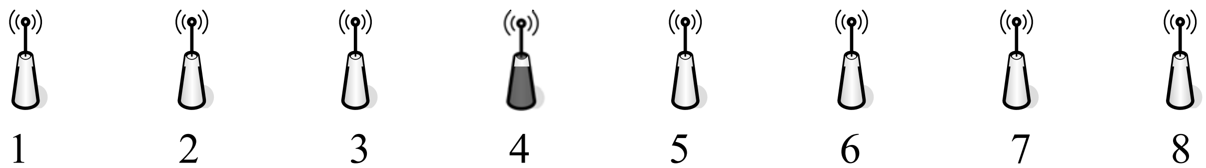
$$H(x)=\frac{1}{n}\left[\left(x-\frac{n+1}{2}\right)^2+\frac{n^2-1}{4}\right]$$

To minimize *H(x), we have*

$$x=\left\lfloor\frac{n+1}{2}\right\rfloor \quad or \quad x=\left\lceil\frac{n+1}{2}\right\rceil$$

One Gateway

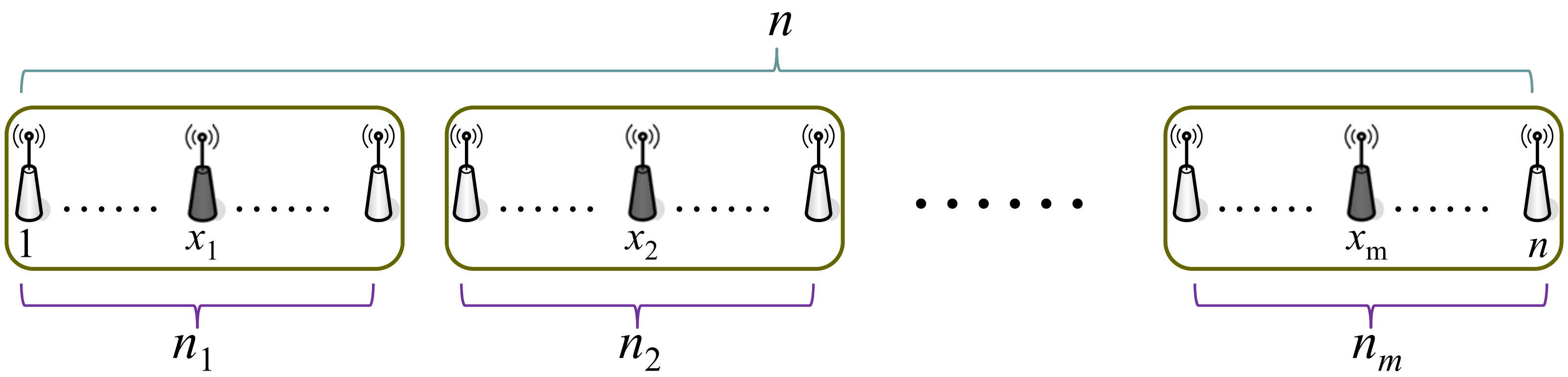
$$n = 9 \Rightarrow x = \left\lfloor \frac{n+1}{2} \right\rfloor = 5$$



$$n = 8 \Rightarrow x = \left\lfloor \frac{n+1}{2} \right\rfloor = 4$$

Multiple Gateways

How to select *m* gateways from *n* APs?



$$H_i(x_i) = \frac{1}{n_i}\left[\left(x_i - \frac{n_i + 1}{2}\right)^2 + \frac{n_i^2 - 1}{4}\right]$$

Average number of hops of each group.

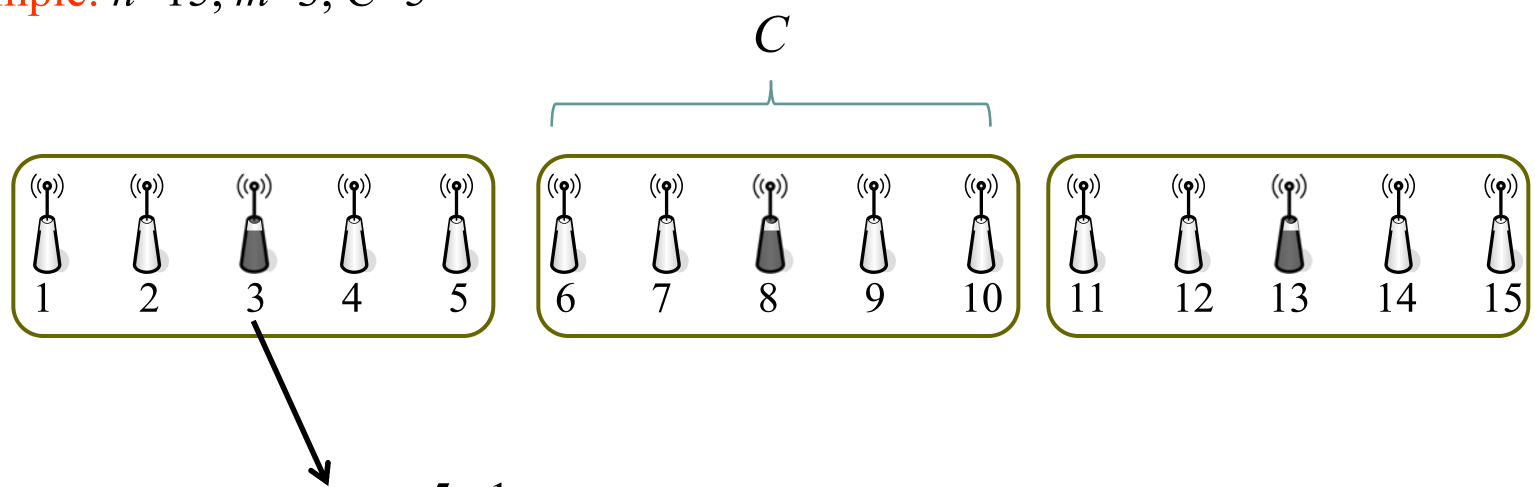
Multiple Gateways

Let $C = \frac{n}{m}$ be the number of APs in a group

Case1: C is an odd integer:

$$x_i = \frac{C+1}{2} + (i-1)C$$

Example: n=15, m=3, C=5



$$x_1 = \frac{5+1}{2}$$

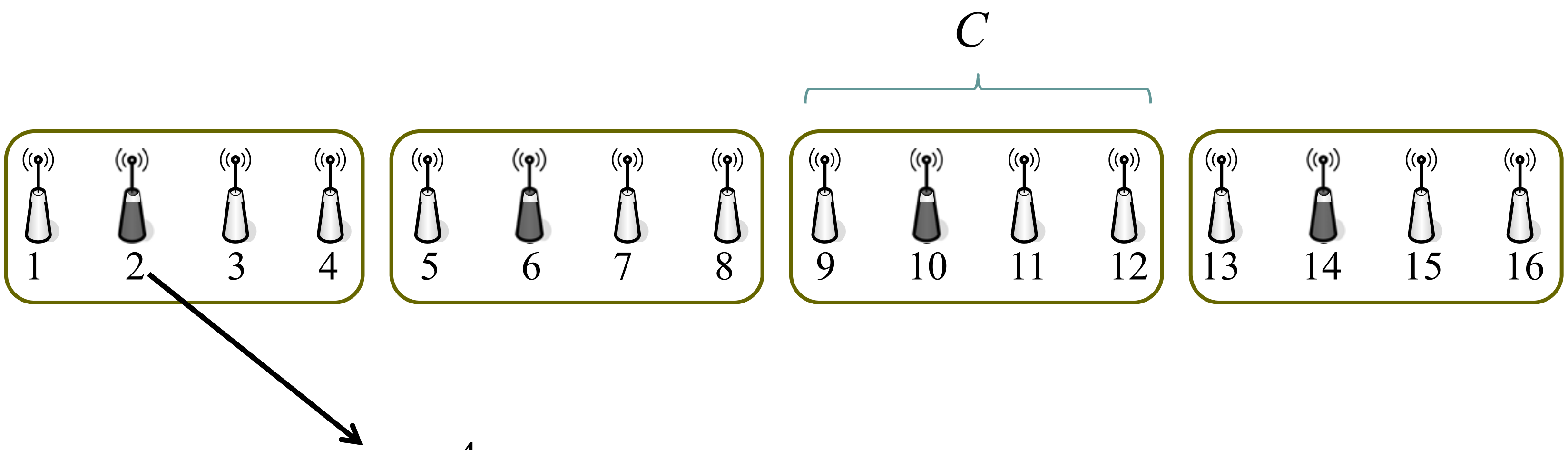
Multiple Gateways

Let $C = \frac{n}{m}$ be the number of APs in a group

Case2: C is an even integer:

$$x_i = \frac{C}{2} + (i-1)C$$

Example: n=16, m=4, C=4



$$x_1 = \frac{4}{2}$$

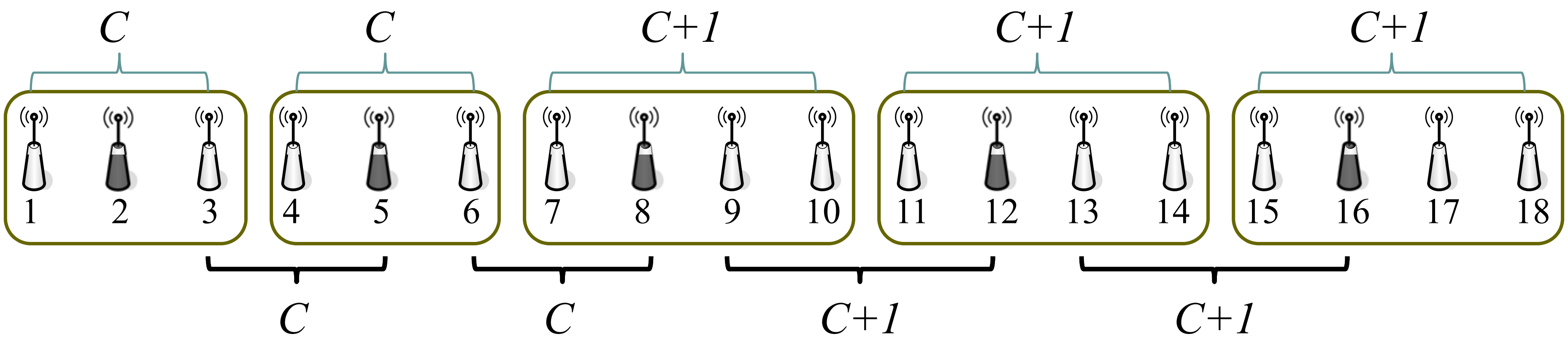
Multiple Gateways

Let $C = \frac{n}{m}$ be the number of APs in a group

Case3: C is not an integer but exists $k(1 \leqq k \leqq m)$ such that $C=(n-k)/m$ is an odd integer :

$$x_i = \begin{cases} \frac{C+1}{2} + (i-1)C & , if\ 1 \le i \le m-k+1 \\ x_{m-k+1} + [i-(m-k+1)](C+1) & , if\ m-k+2 \le i \le m \end{cases}$$

Example: n=18, m=5, C=3



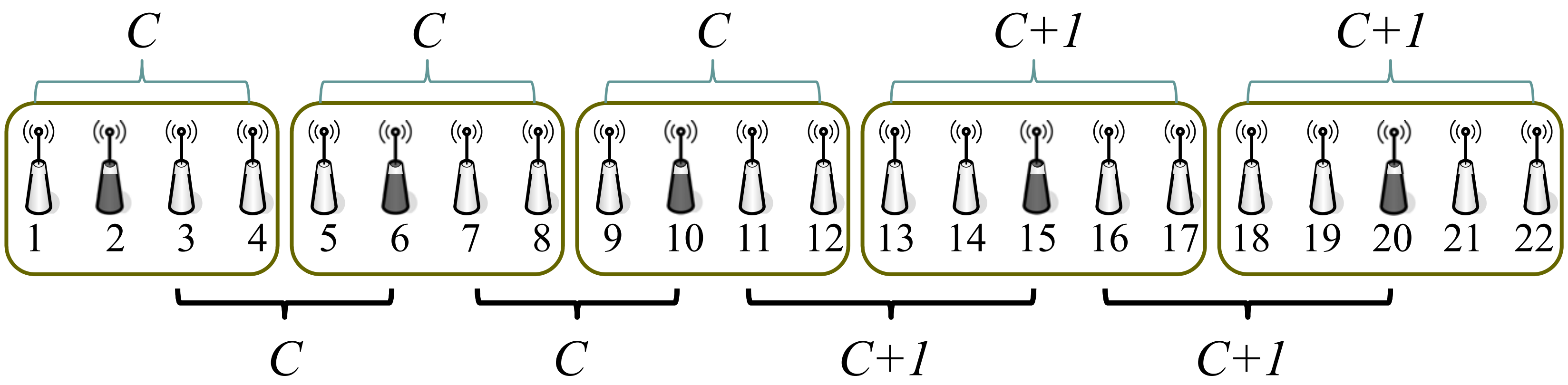
Multiple Gateways

Let $C = \frac{n}{m}$ be the number of APs in a group

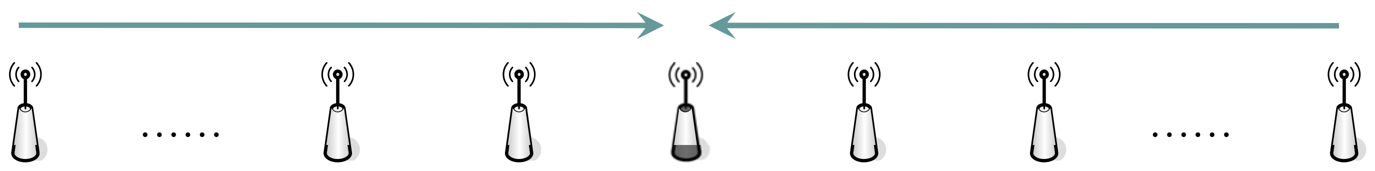
Case3: C is not an integer but exists $k(1 \leqq k \leqq m)$ such that $C=(n-k)/m$ is an even integer :

$$x_i = \begin{cases} \frac{C}{2} + (i-1)C & , if\ 1 \le i \le m-k \\ x_{m-k} + [i-(m-k)](C+1) & , if\ m-k+1 \le i \le m \end{cases}$$

Example: n=22, m=5, C=4



Energy Balance



越靠近 Gateway的AP所要代傳封包量越多，耗費越多電量

Energy Balance

T. Rappaport, *Wireless Communications: Principles and Practice*, 2nd ed. Prentice-Hall PTR, 2002.

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 L d^\gamma}$$

P_t : transmitted power

P_r : received power

G_t : antenna gains for the transmitter

G_r : antenna gains for the receiver

$L (L \geq 1)$: the system loss factor

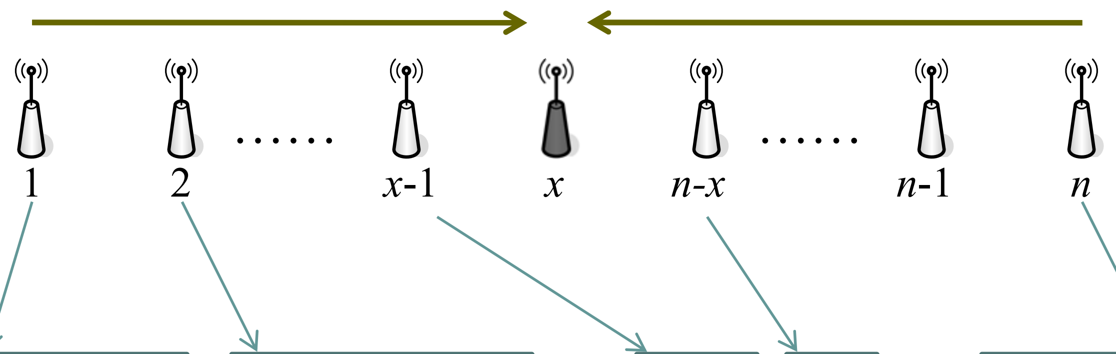
λ : the wavelength

γ : the path loss exponent

Energy Balance

Given n APs and the gateway has been known,
how to determine the distance of neighboring APs for achieving energy balance?

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 L d^\gamma} \Rightarrow P_t = \boxed{P_r \frac{(4\pi)^2 L}{G_t G_r \lambda^2}} d^\gamma = T d^\gamma$$



$$P = \boxed{(d_1^\gamma + d_2^\gamma + \ldots + d_{x-1}^\gamma)T} + \boxed{(d_2^\gamma + \ldots + d_{x-1}^\gamma)T} + \ldots + \boxed{d_{x-1}^\gamma T} + \boxed{d_x^\gamma T} + \ldots + \boxed{(d_x^\gamma + d_{x+1}^\gamma + \ldots + d_{n-1}^\gamma)T}$$

越靠近 Gateway的AP所要代傳封包量越多，耗費越多電量➔ AP 間距離越小!

One Gateway

$$P = (d_1^\gamma + d_2^\gamma + \ldots + d_{x-1}^\gamma)T + (d_2^\gamma + \ldots + d_{x-1}^\gamma)T + \ldots + d_{x-1}^\gamma T + d_x^\gamma T + \ldots + (d_x^\gamma + d_{x+1}^\gamma + \ldots + d_{n-1}^\gamma)T$$

$$P = \{[d_1^\gamma + 2d_2^\gamma + \ldots + (x-1)d_{x-1}^\gamma] + [d_{n-1}^\gamma + 2d_{n-2}^\gamma + \ldots + (n-x)d_x^\gamma]\}T$$

$$P = \left(\sum_{i=1}^{x-1} i d_i^\gamma + \sum_{j=1}^{n-x} j d_{n-j}^\gamma \right) T$$

One Gateway

算術平均數 ≥ 幾何平均數

$$\frac{\sum_{i=1}^{x-1} id_i^{\gamma} + \sum_{j=1}^{n-x} jd_{n-j}^{\gamma}}{n-1} \geq \left\{\left(\prod_{i=1}^{x-1} id_i^{\gamma}\right)\left(\prod_{j=1}^{n-x} jd_{n-j}^{\gamma}\right)\right\}^{\frac{1}{n-1}}$$

$$P \geq (n-1)\left\{\left(\prod_{i=1}^{x-1} id_i^{\gamma}\right)\left(\prod_{j=1}^{n-x} jd_{n-j}^{\gamma}\right)\right\}^{\frac{1}{n-1}} T$$

The equality holds when $id_i^{\gamma} = jd_{n-j}^{r}$ for all $i \in [1, x-1]$ and $j \in [1, n-x]$

$$P = \left(\sum_{i=1}^{x-1} id_i^{\gamma} + \sum_{j=1}^{n-x} jd_{n-j}^{\gamma}\right) T$$

One Gateway

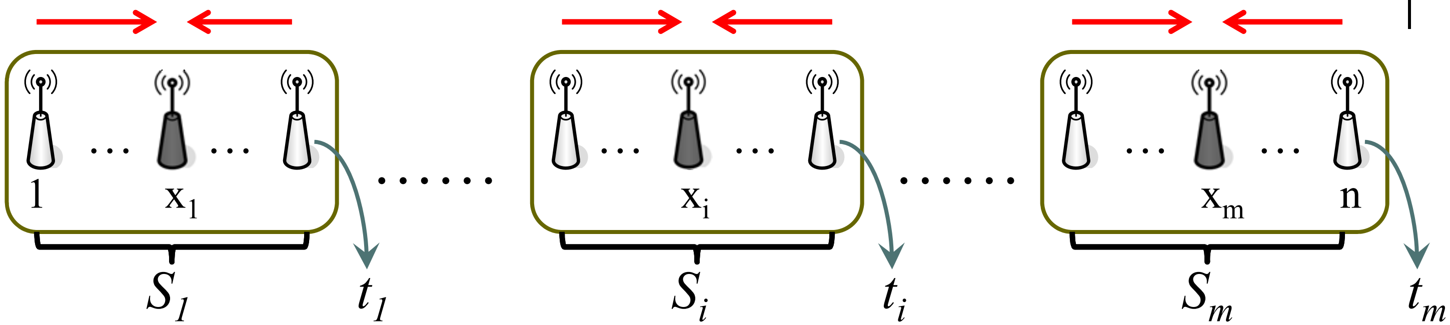
Since $\sum_{i=1}^{x-1} d_i + \sum_{j=1}^{n-x} d_j = L$

The minimum value of P can be achieved when

$$d_i = \begin{cases} \left(\sum_{i=1}^{x-1} i^{-\frac{1}{\gamma}} + \sum_{i=x}^{n-1} (n-i)^{-\frac{1}{\gamma}} \right)^{-1} L , & for\ i = 1 \\ i^{-\frac{1}{\gamma}} d_1 & , for\ i \in [2, x-1] \\ (n-i)^{-\frac{1}{\gamma}} d_1 & , for\ i \in [x, n-1] \end{cases}$$

越靠近 Gateway的AP所要代傳封包量越多，耗費越多電量➔ AP 間距離越小!

Multiple Gateways



$$P=\{[d_1^\gamma+2d_2^\gamma+\ldots+(x_1-1)d_{x_1-1}^\gamma]+[d_{t_1-1}^\gamma+2d_{t_1-2}^\gamma+\ldots+(t_1-x_1)d_{x_1}^\gamma]\}T$$

$$+\{[d_{t_1+1}^\gamma+2d_{t_1+2}^\gamma+\ldots+(x_2-1)d_{x_2-1}^\gamma]+[d_{t_2-1}^\gamma+2d_{t_2-2}^\gamma+\ldots+(t_2-x_2)d_{x_2}^\gamma]\}T$$

$$+\ldots$$

$$+\{[d_{t_{m-1}+1}^\gamma+2d_{t_{m-1}+2}^\gamma+\ldots+(x_m-1)d_{x_m-1}^\gamma]+[d_{n-1}^\gamma+2d_{n-2}^\gamma+\ldots+(n-x_m)d_{x_m}^\gamma]\}T$$

$$P=\sum_{k=1}^{m}\left(\sum_{i=1}^{x_k-1} i d_{t_{k-1}+i}^\gamma+\sum_{j=1}^{t_k-x_k} j d_{t_k-j}^\gamma\right)T$$

Multiple Gateways

$$P \geq (n-1)\prod_{k=1}^{m}\left(\left(\prod_{i=1}^{x_k-1} id_{t_{k-1}+i}^{\gamma}\right)\left(\prod_{j=1}^{t_k-x_k} jd_{t_k-j}^{\gamma}\right)\right)^{\frac{1}{n-1}} T$$

The equality holds when $id_{t_{k-1}+i}^{\gamma} = jd_{t_l-j}^{r}$ for all $i \in [1, x_k - 1]$, $j \in [1, t_k - x_k]$, and $k, l \in [1, m]$

$$P = \sum_{k=1}^{m}\left(\sum_{i=1}^{x_k-1} id_{t_{k-1}+i}^{\gamma} + \sum_{j=1}^{t_k-x_k} jd_{t_k-j}^{\gamma}\right) T$$

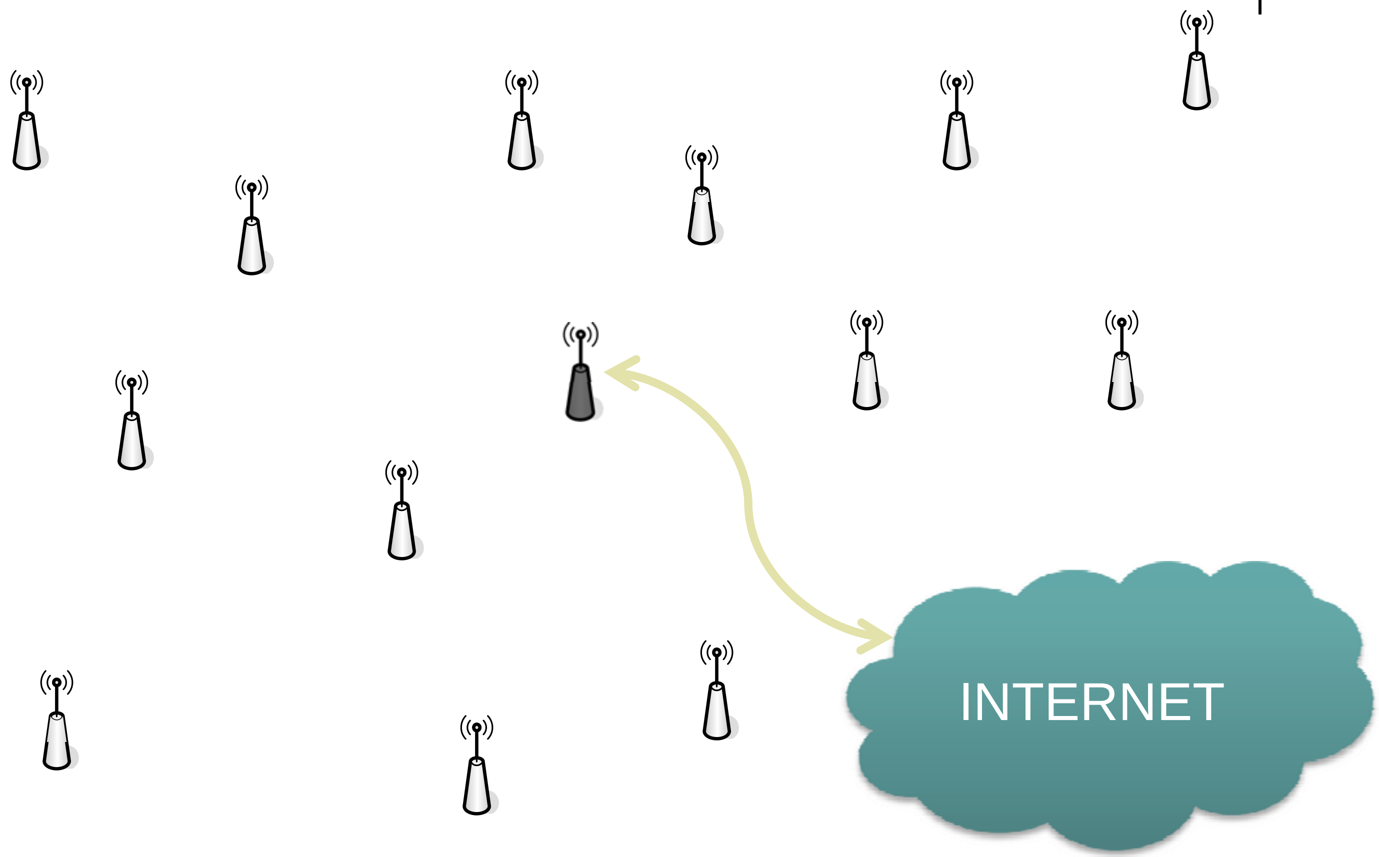
Multiple Gateways

$$\text{Since } \sum_{k=1}^{m}\left(\sum_{i=1}^{x_k-1} d_{t_{k-1}+i} + \sum_{j=1}^{t_k-x_k} d_{t_k-j}\right) = L$$

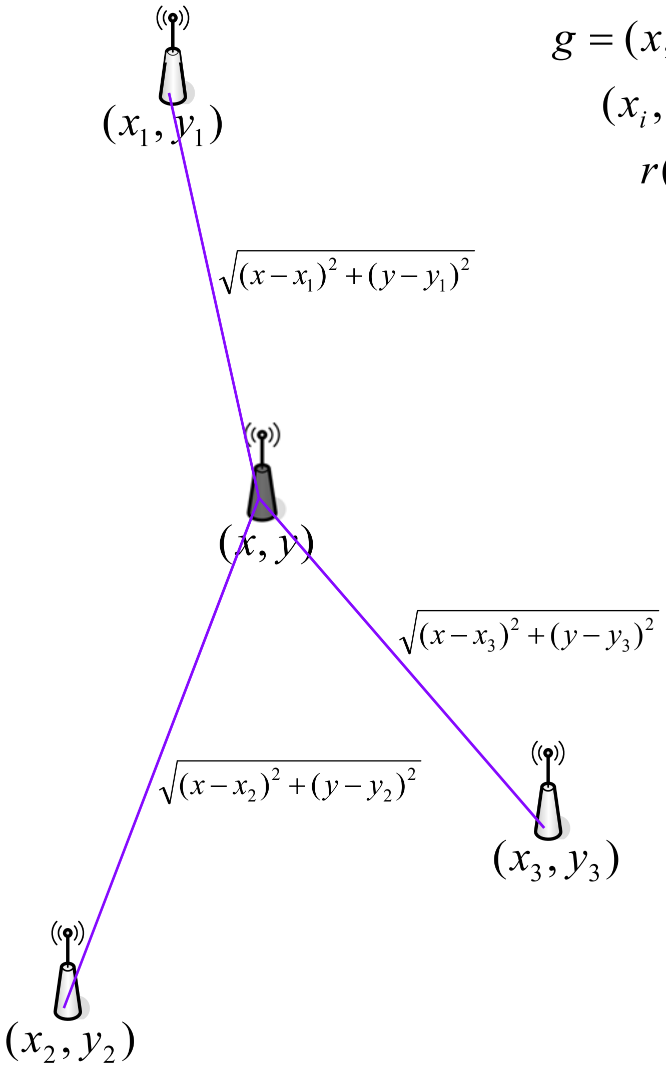
The minimum value of P can be achieved when

$$d_i = \begin{cases} \left(\sum_{k=1}^{m}\left(\sum_{i=1}^{x_k-1} i^{-\frac{1}{\gamma}} + \sum_{j=x_k}^{t_k-x_k} (t_k - j)^{-\frac{1}{\gamma}}\right)\right)^{-1} L \text{ , } for\ i = t_k + 1 \\ i^{-\frac{1}{\gamma}} d_1 \text{ , } for\ i \in [t_k + 2, x_{k+1} - 1] \\ (t_{k+1} - i)^{-\frac{1}{\gamma}} d_1 \text{ , } for\ i \in [x_{k+1}, t_{k+1} - 1] \end{cases}$$

2-D Vehicular Networks



One Gateway



$g=(x,y)$ denotes the location of the gateway

(x_i, y_i) denotes the location of AP i

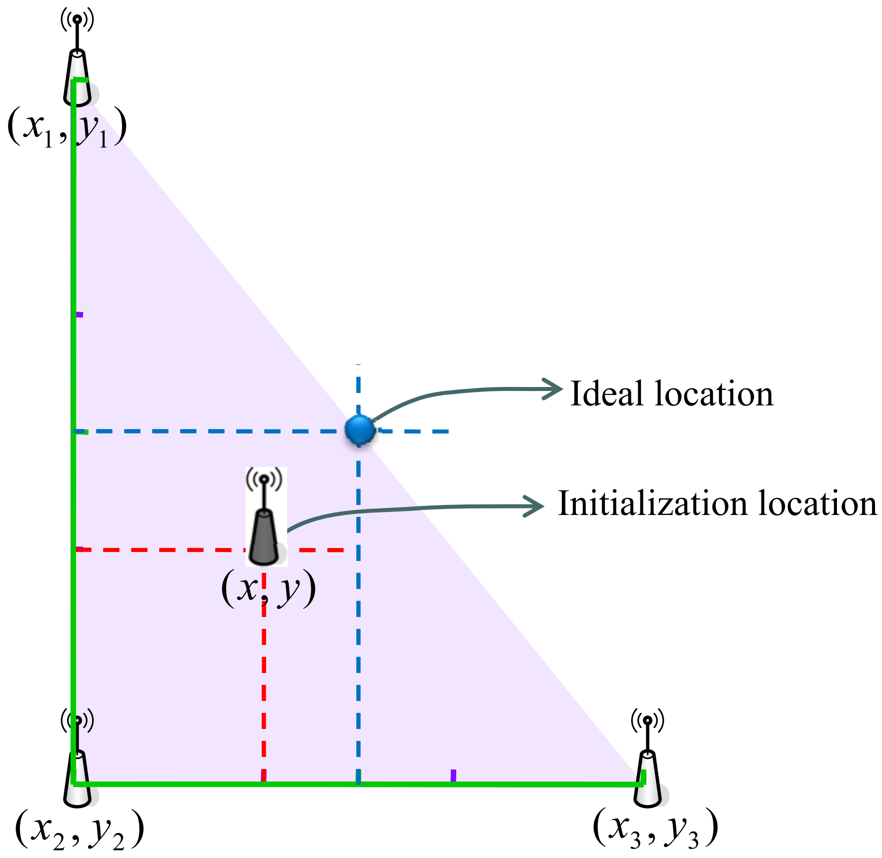
$r(n)$ denotes the common transmission range for all n APs

The number of hops from AP_i to gateway $\geq \left\lceil \frac{\sqrt{(x-x_i)^2+(y-y_i)^2}}{r(n)} \right\rceil$

To minimize *H(g), we have*

$$\text{Minimize} \left\{ f(x,y) = \sum_{i=1}^{n} \sqrt{(x-x_i)^2+(y-y_i)^2} \right\}$$

One Gateway



1. Initialization:

$$x = \frac{1}{n}\sum_{i=1}^{n} x_i$$

$$y = \frac{1}{n}\sum_{i=1}^{n} y_i$$

→ Not the ideal location

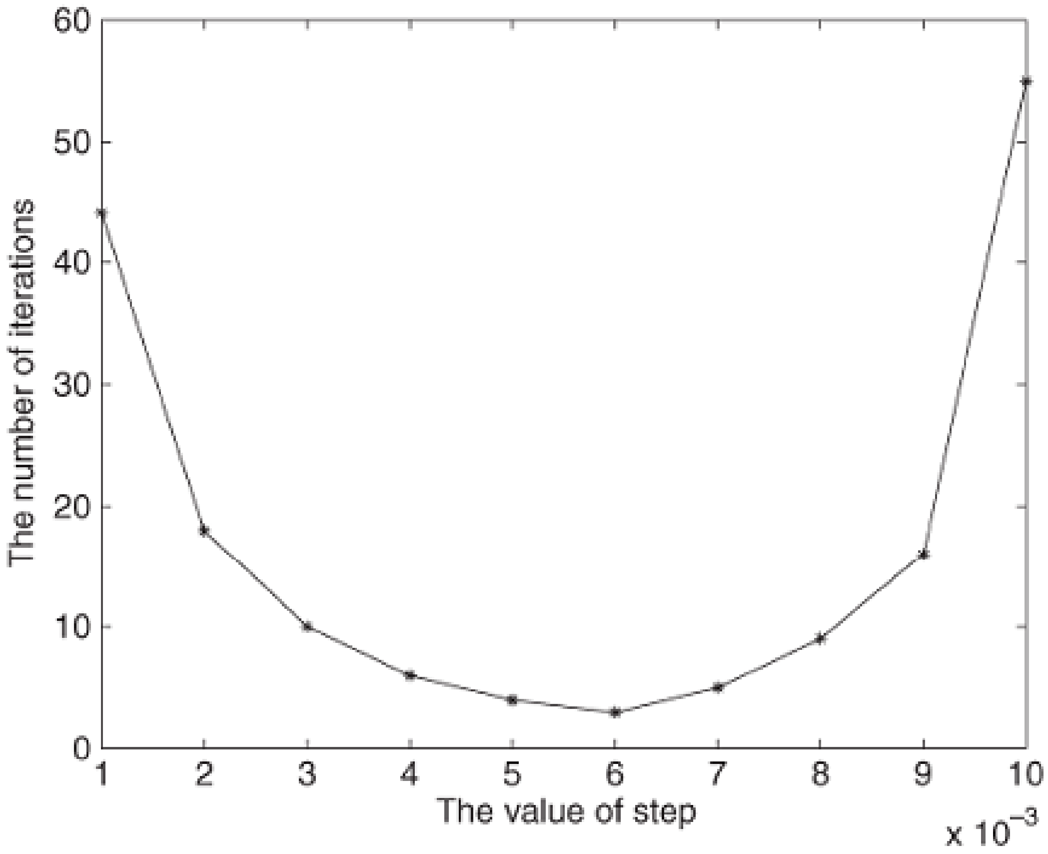
2. Iteration: calculate *Scos* and *Ssin*, where

$$Scos = \sum_{i=1}^{n} \frac{(x_i - x)}{\sqrt{(x-x_i)^2 + (y-y_i)^2}}$$

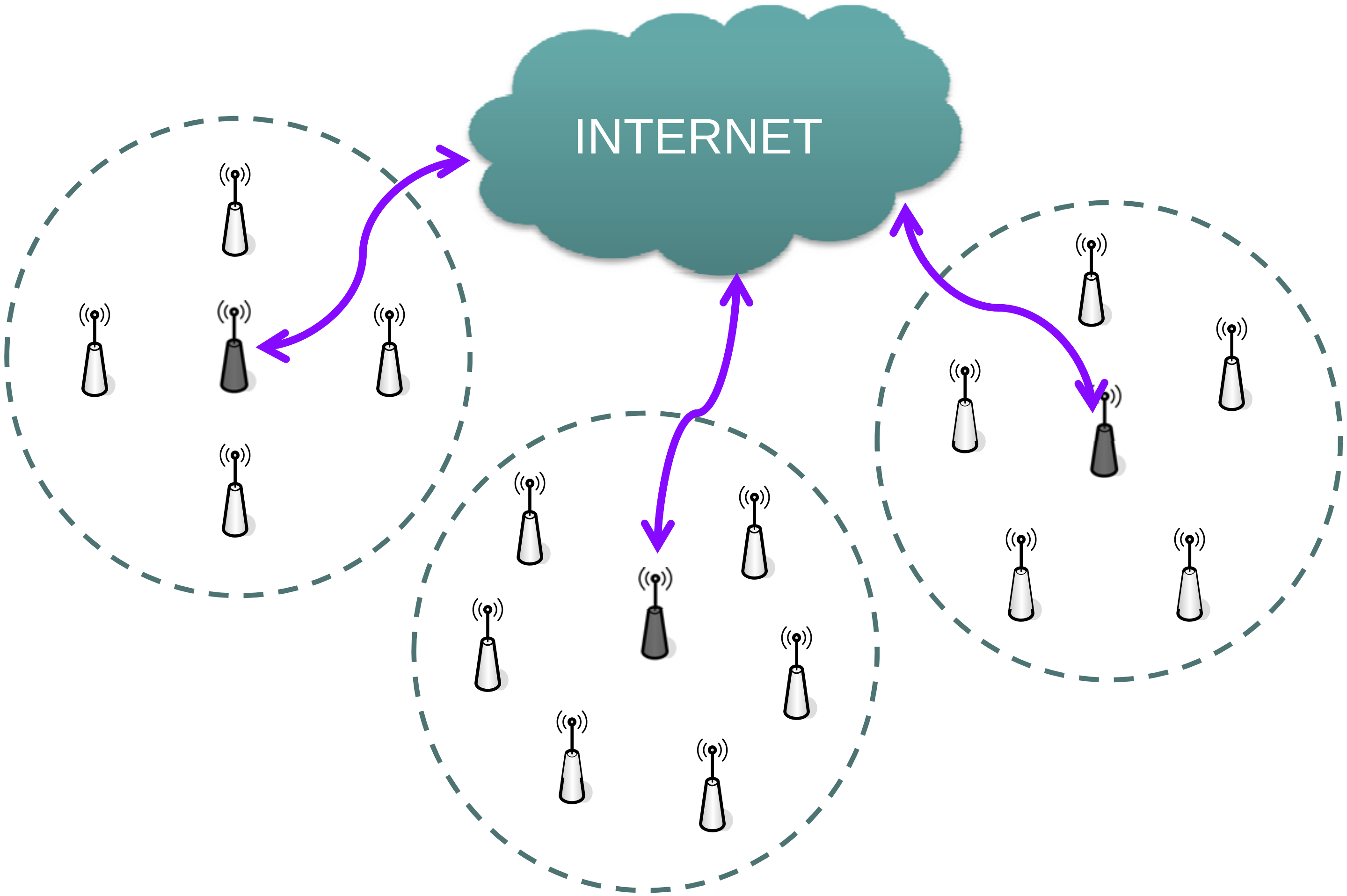
$$Ssin = \sum_{i=1}^{n} \frac{(y_i - y)}{\sqrt{(x-x_i)^2 + (y-y_i)^2}}$$

3. IF |*Scos*|≤*Threshold* and |*Ssin*|≤*Threshold*
4. Go to 9.
5. Else
6. *x*=*x*+*step***Scos* and *y*=*y*+*step***Ssin*
7. Go to 2.
8. END IF
9. Finish

One Gateways



Multiple Gateways



Discussion-Power

$$P = P_t H(G)$$

P_t is the transmission power, which is the same for all APs,
G is the gateways in the network
$H(G)$ is the average number of hops from an AP to a gateway

When $H(G)$ is minimized, the average transmission power P is also minimized.

Discussion-Capacity

$$\lambda \cdot H(G) \cdot n \leq C$$

λ denotes the AP generates traffics.
C denotes the capacity of the network.
H(*G*) is the average number of hops from an AP to a gateway.
n is the total number of APs in the network.

Therefore, the capacity available to each node, λ, is bounded by

$$\lambda \leq \frac{C}{nH(G)} \leq \frac{C}{nH_{\min}(G)}$$

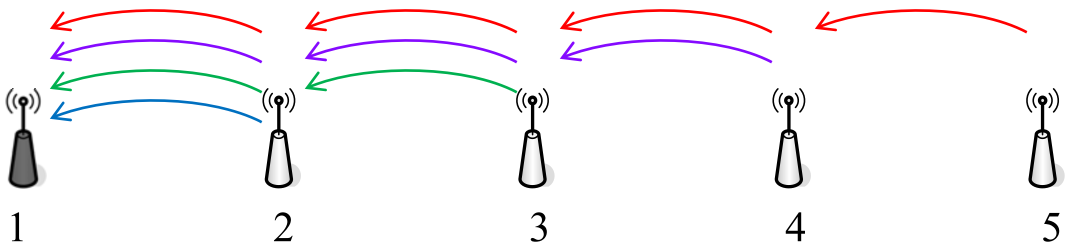
When *H(G)* is minimized, the capacity of APs can be maximized.

Discussion-Capacity

$C = 60$ Mbps
$n = 5$

$$H(G) = 1.2 \;\Rightarrow n \times H(G) = 6$$

$$\Rightarrow \lambda = 10 \text{ Mbps}$$



$$H(G) = 2 \;\Rightarrow n \times H(G) = 10$$

$$\Rightarrow \lambda = 6 \text{ Mbps}$$

When *H(G)* is minimized, the capacity of APs can be maximized.

Conclusion

- Optimally placing gateways.
  - Minimize the average number of hops from APs to gateways.
  - Minimize the total power consumption.
  - Maximize the average capacity of each AP.

On Scheduling Vehicle-Roadside Data Access

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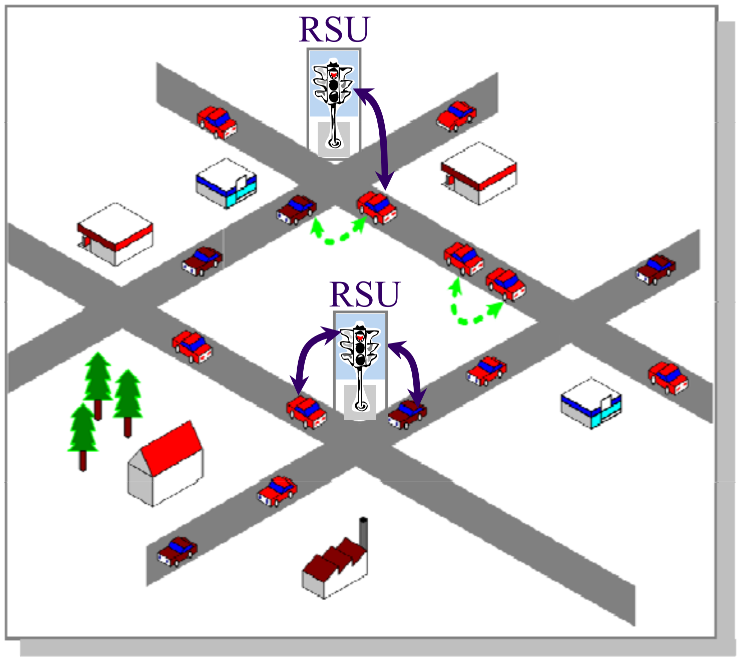
ACM VANET 2007

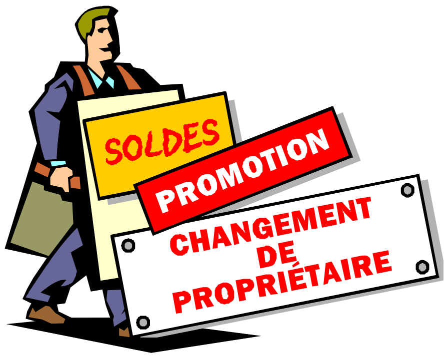
Introduction – The Architecture of Vehicle (Roadside service)

- **V**ehicular **A**d-hoc **NET**works includes
  - Moving Vehicles, and
  - Roadside Units (RSU).
    - Local broadcasting information
    - IEEE 802.11 access point



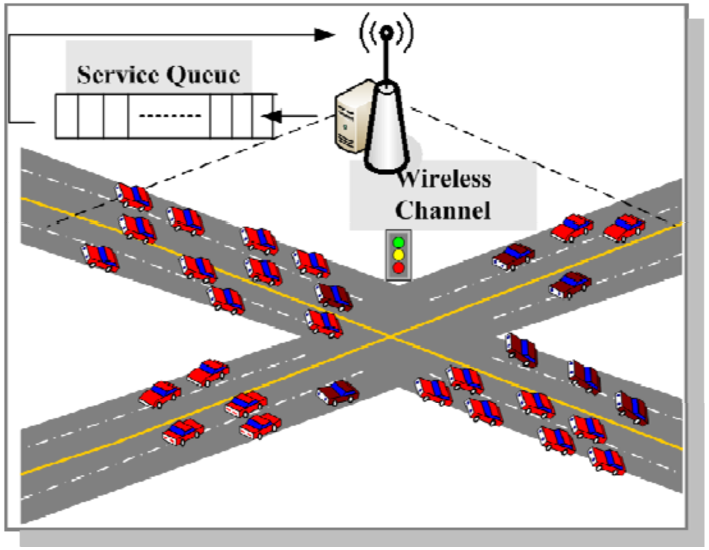
Introduction – The Architecture of Vehicle (Roadside service)

- Applications of the RSU
  - Commercial Advertisement
  - Real-Time Traffic
  - Digital Map Downloading



Introduction – Challenges

- Bandwidth Competition
  - All requests (upload/download) compete for the same limited bandwidth
- Time Constraint
  - Vehicles are moving and they only stay in the RSU area for a short period of time
- Data Upload / Download
  - The miss of upload leads to data staleness



Problem

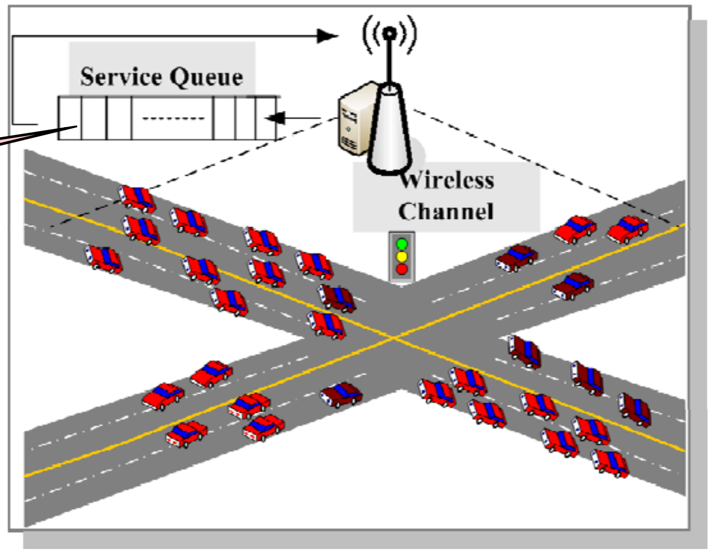
- How to develop a scheduling algorithm for data access?

- Performance Metrics (Tradeoff)
  - Service Ratio (下載資訊服務的成功率)
    - Ratio of the number of requests served before the service deadline to the total number of arriving requests.
  - Data Quality (車子上傳資訊更新資料)
    - Percentage of fresh data access

System Model

- Each request is characterized by
  - *v-id* : the Vehicle-ID
  - *d-id* : the Data-ID
  - *op* : upload / download
  - *deadline* : Time Constraint

(*v-id* , *d-id* , *op* , *deadline*)

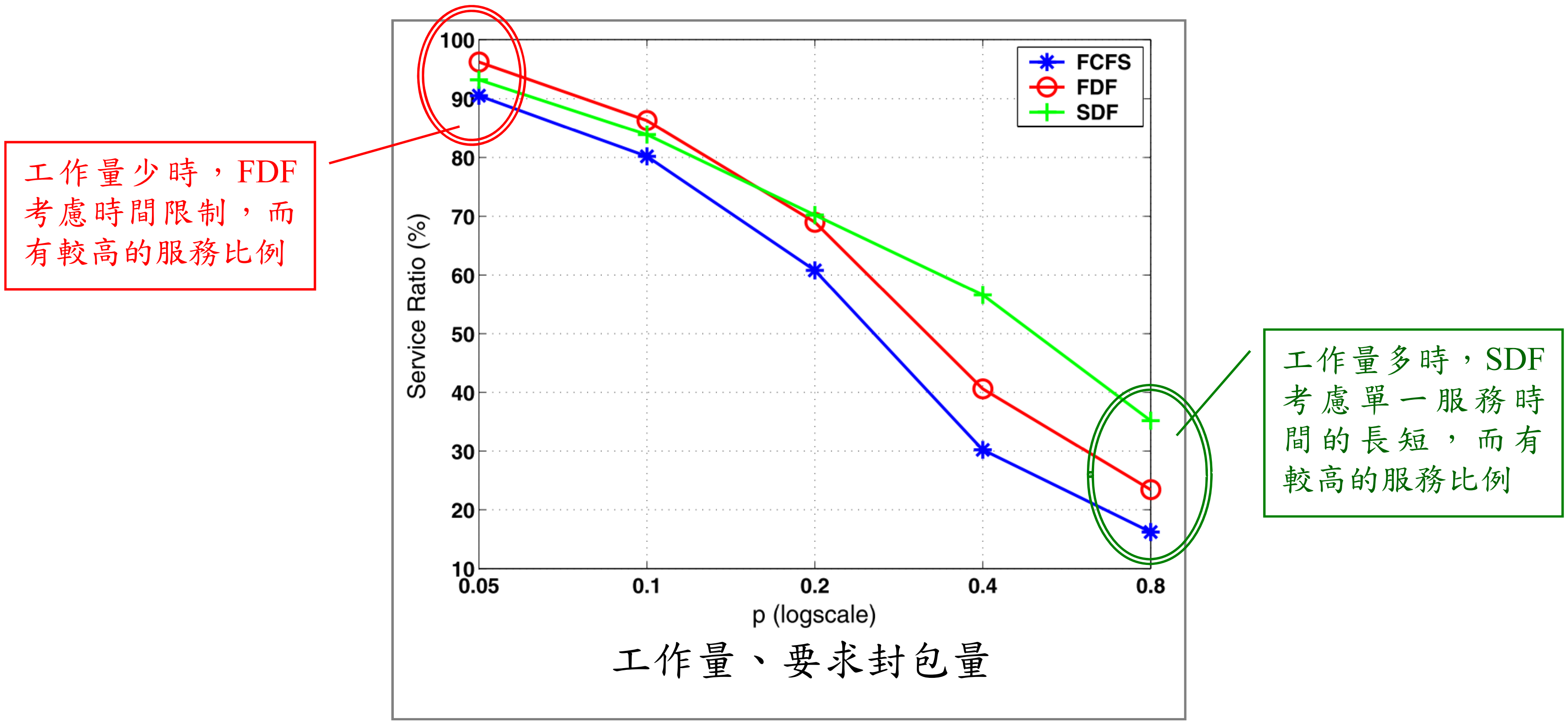


System Model

- Assumptions
  - Each vehicle knows the service deadline of its request.
    - Location-aware (GPS)
    - Deadline-aware (driving velocity)
  - The RSU maintains a service cycle
  - Service **non-preemptive**

Naive Scheduling Policies

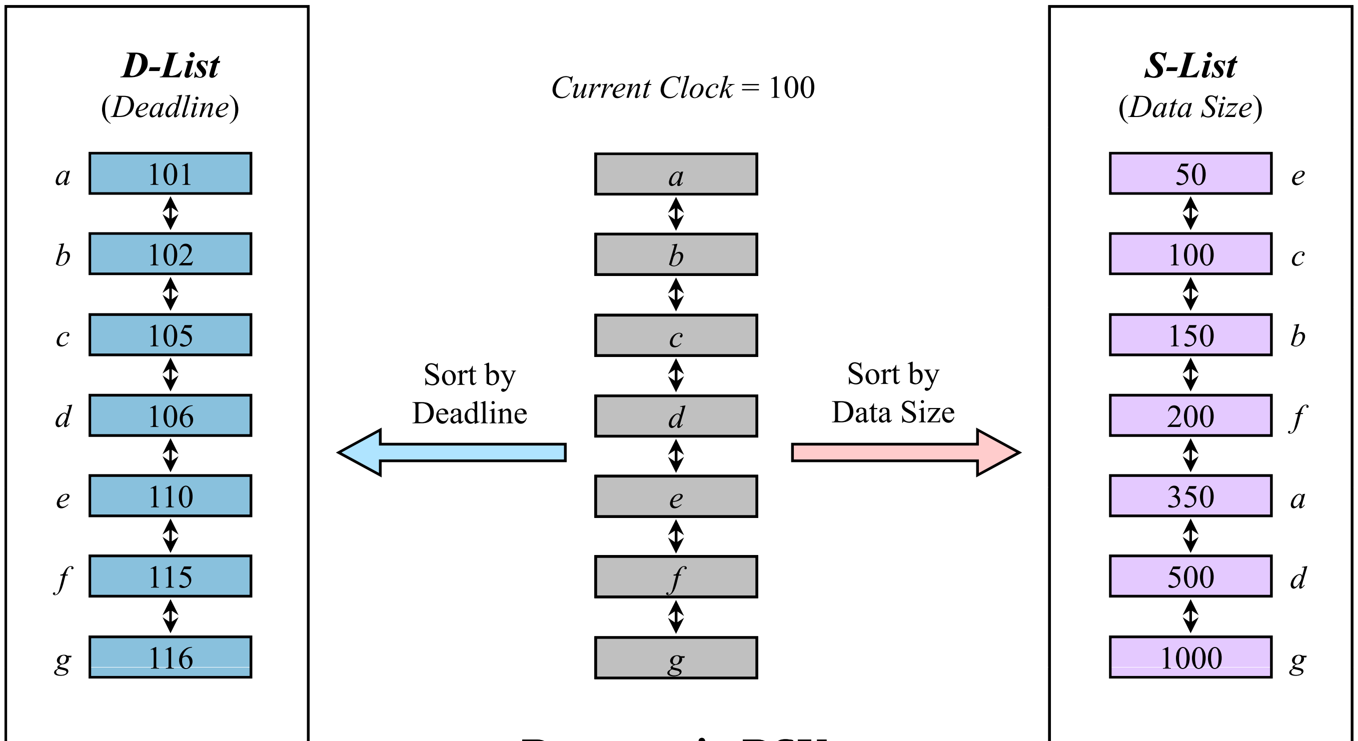
- First Come First Serve (**FCFS**)
- First Deadline First (**FDF**)
- Smallest Datasize First (**SDF**)



Scheduling Scheme I

– *D*S* Scheduling

- *D*S* Scheduling
  - D : D-List (Deadline-list)
  - S : S-List (DataSize-list)



Requests in RSU

Scheduling Scheme I

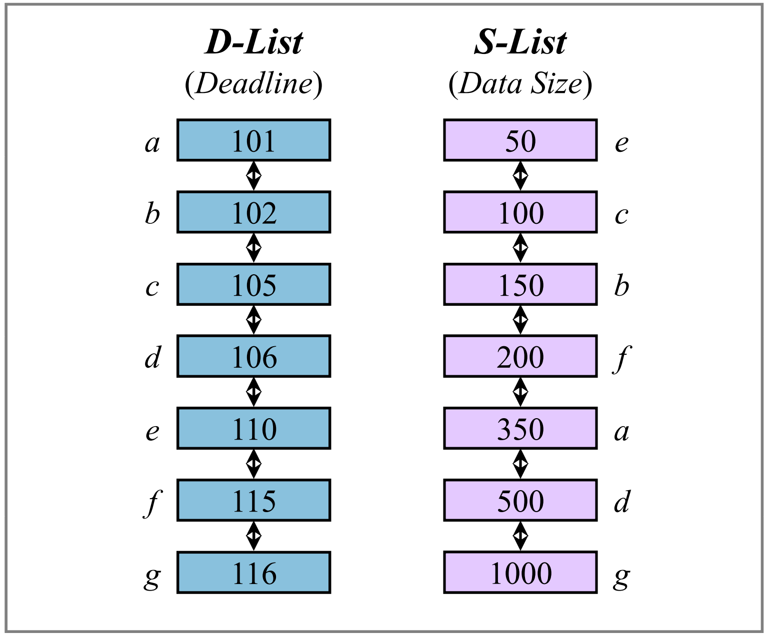
– *D*S* Scheduling

- Basic Idea
  - Given two requests with the same deadline, the one asking for a small size data should be served first.
  - Given two requests asking for the data items with same size, the one with an earlier deadline should be served first.
  - Assign each arrival request a *service value* based on its deadline and data size, called ***DS_value*** as its service priority weight

$$DS\_value = (Deadline - CurrentClock) * DataSize$$

Scheduling Scheme I
– *D*S* Scheduling Implementation

Information in RSU



Current Clock **= 100**

Scheduling Scheme I
– *D*S* Scheduling Implementation

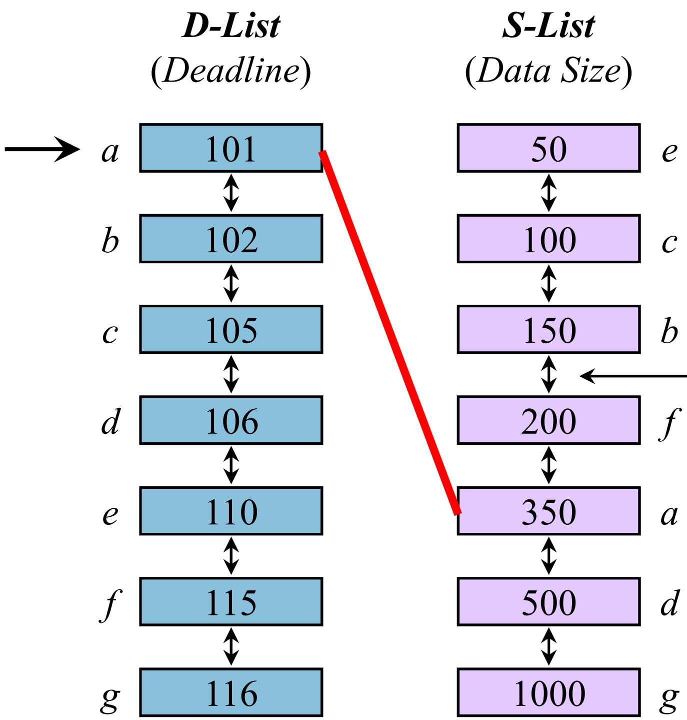
Step 1

MinDS
= (*Deadline* - *CurrentClock*) * *DataSize*
= (101-100) * 350 = 350

Current Clock = 100

目前最小的 *DS_Value* 為 350，
而 *D-List* 次要緊急的 entry 為 request *b*；
若 request *b* 要有更小的 *DS_Value*，
則與其配對的 *DataSize* 必須小於 *MinS*

也就是 ***MinS* = 350 / (102-100) = 175**



MinS = 175

Scheduling Scheme I

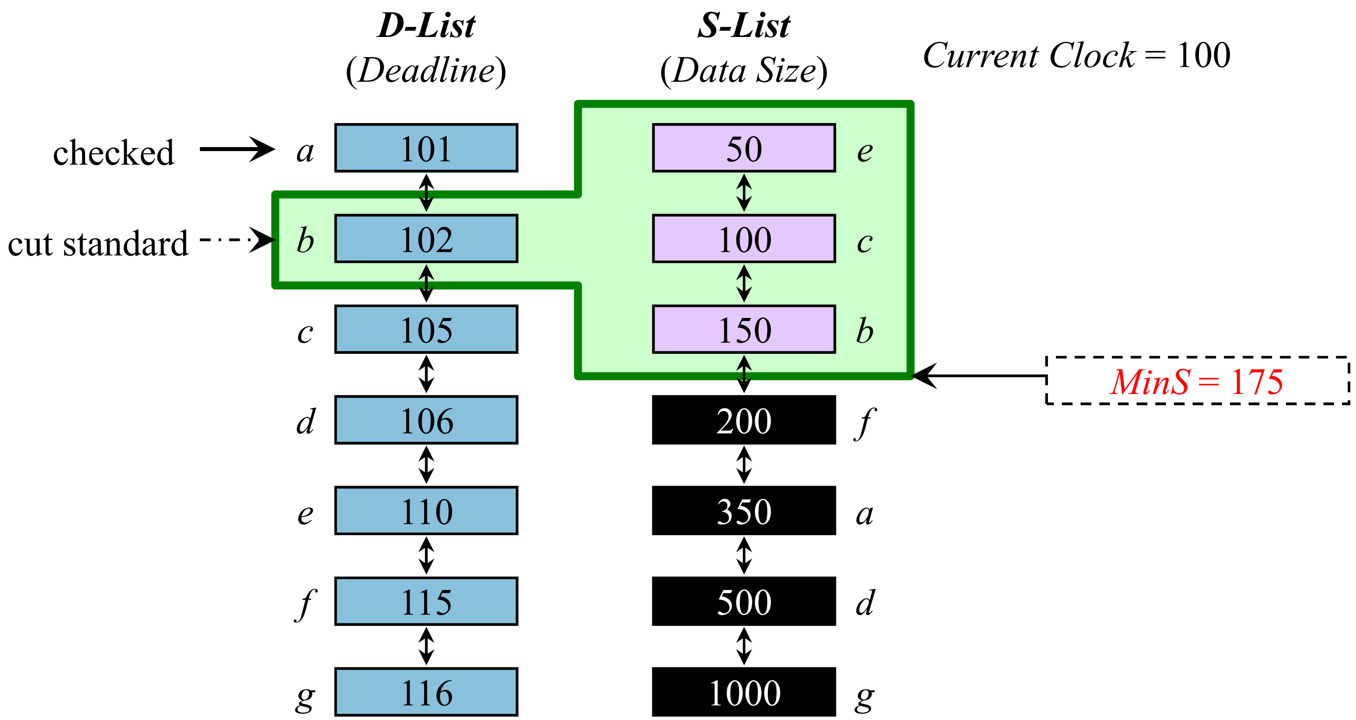
– *D*S* Scheduling Implementation

Step 1

MinDS

= (*Deadline* - *CurrentClock*) * *DataSize*

= (101-100) * 350 = 350



Scheduling Scheme I
– *D*S* Scheduling Implementation

Step 2

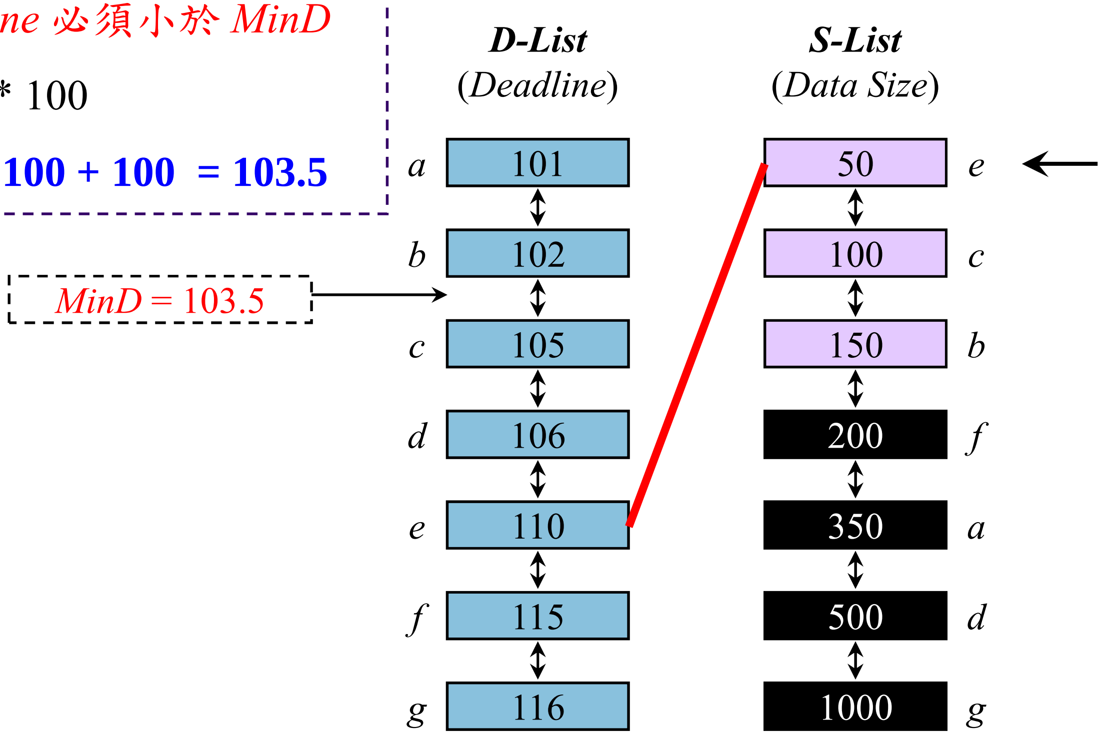
Current Clock = 100

目前最小的 *DS_Value* 依然為 350，
而 *S-List* 次大的 entry 為 request *c*；
若 request *c* 要有更小的 *DS_Value*，
則與其配對的 *Deadline* 必須小於 *MinD*

350 > (*MinD* – 100) * 100

也就是 ***MinD* = 350 / 100 + 100 = 103.5**

***DS_Value* (request *e*)**
= (*Deadline* - *CurrentClock*) * *DataSize*
= (110-100) * 50 = 500 > ***MinDS*** = 350

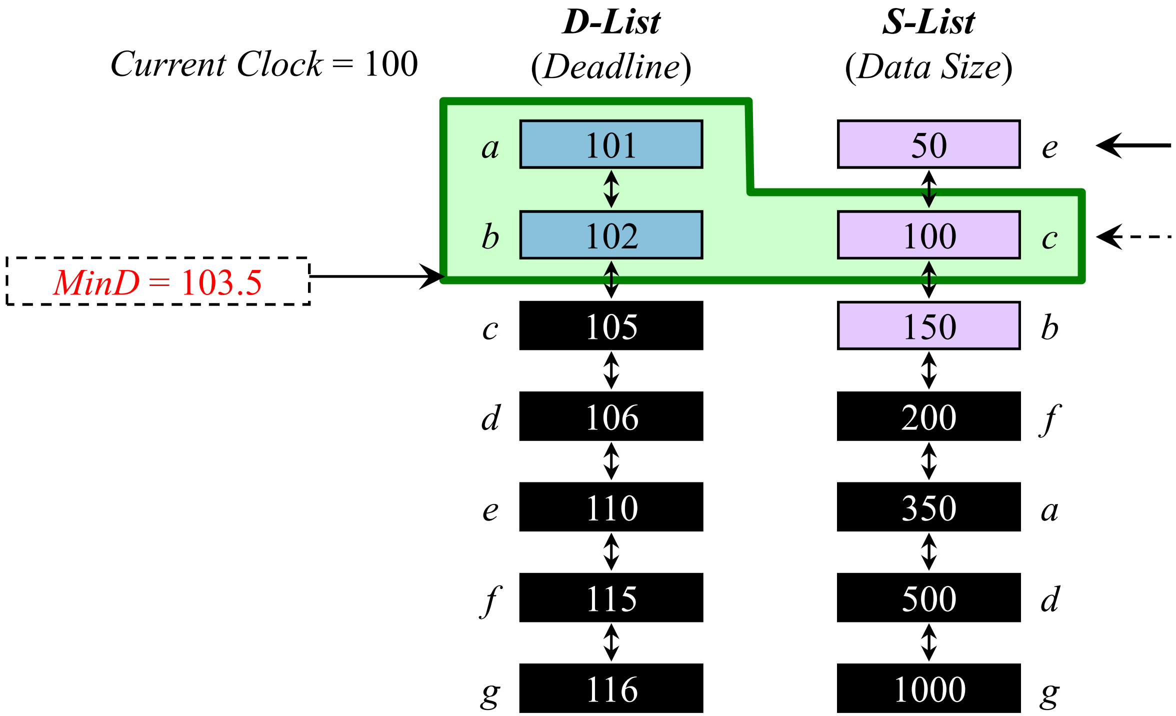


Scheduling Scheme I

– *D*S* Scheduling Implementation

Step 2

***DS_Value* (request *e*)**
= (*Deadline* - *CurrentClock*) * *DataSize*
= (110-100) * 50 = 500 > ***MinDS*** = 350



Scheduling Scheme II

– Download Optimization: Broadcasting

- Observation
  - several requests may ask for downloading the same data item
  - wireless communication is broadcast in nature
- Basic Idea
  - delay some requested data and broadcast it before the deadlines, then several requests may be served via a single broadcast
  - the data with **more** pending requests should be served first
  - *DSN_value = (Deadline − CurrentClock) * DataSize/Number*

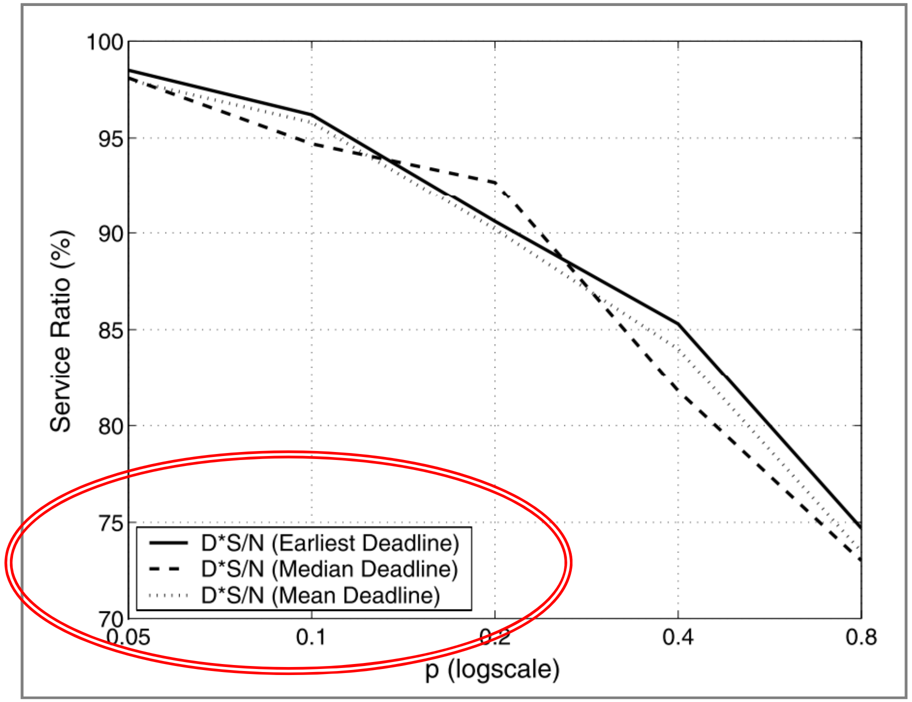
The number of pending requests for the same data (N)

Scheduling Scheme II

– Download Optimization: Broadcasting

- When calculating their *DSN value*, we need to assign each pending request group a single deadline to estimate the urgency of the whole group.

Not too much impact !



Scheduling Scheme II
– The Problem of DSN

- Data Quality will be blocked

  DSN_value = (Deadline − CurrentClock) * DataSize / Number

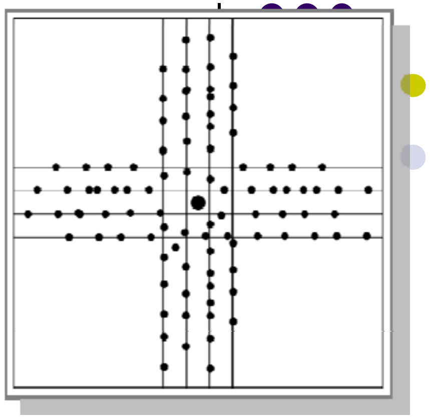
  - For upload request, it is not necessary to maintain several update requests for one data item since only the last update is useful.
  - Number value of update requests is always 1, which makes it not fair for update requests to compete for the bandwidth .
  - D*S/N can improve the system service ratio but block the service opportunity of update requests, which degrades the data quality for downloading.

Scheduling Scheme III

– Upload Optimization (2Step Scheduling)

- Basic Idea
  - two priority queues: one for the update requests and the other for the download requests.
  - the data server provides two queues with different bandwidth (i.e., service probability)

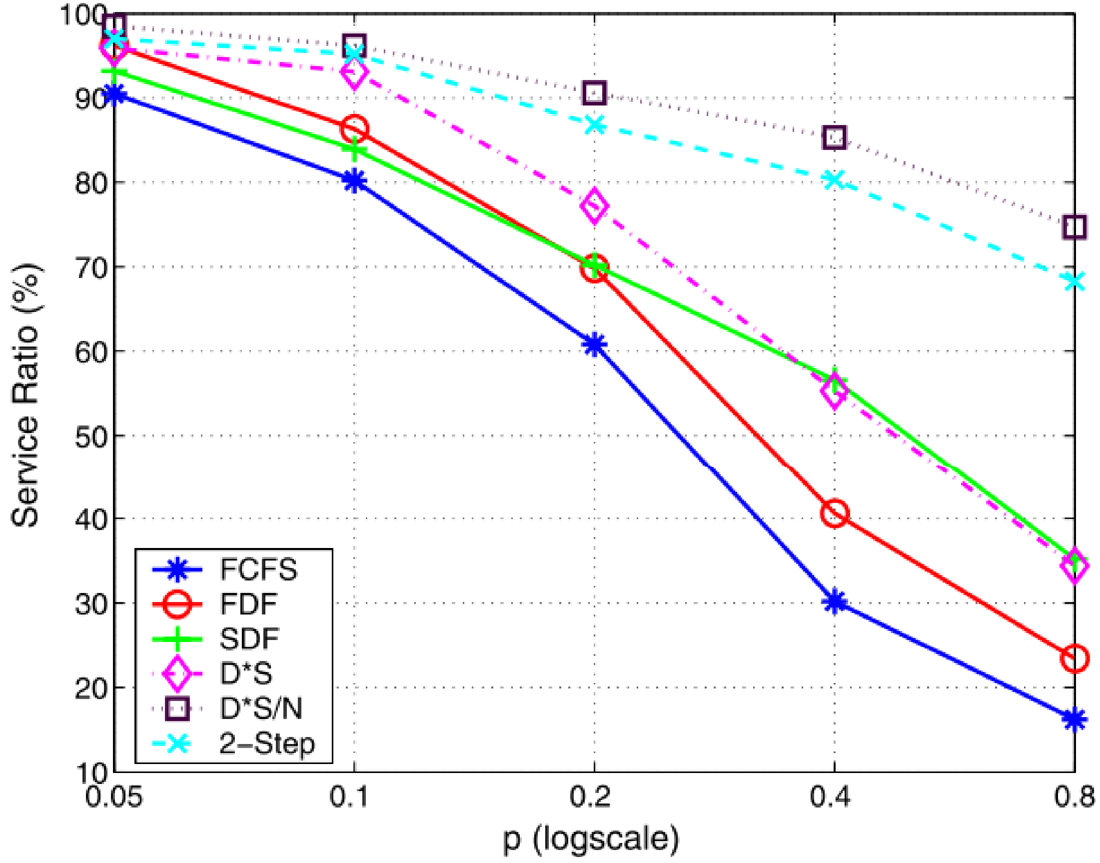
Simulation Setup



- NS-2
- 400m*400m square street scenario
- One RSU server is located at the center of two 2-way roads
- 40 vehicles randomly deployed on each lane
- Each vehicle issues request with a probability *p*
- Access pattern of each data item follows *Zipf* distribution

Parameter	**Value**
Simulation Time	900s
Transmission Rate	$5Mbit/s = 625Kbyte/s$[11]
Vehicle Velocity	15m/s
Wireless Coverage	200 m
Data size	50K $\sim$ 5M, average 2.5M
Vehicle-Vehicle Space	20m
Data set size	25
$Zipf$ Parameter θ	0.8
Update Percentage	10%
Adaptation Window	40s

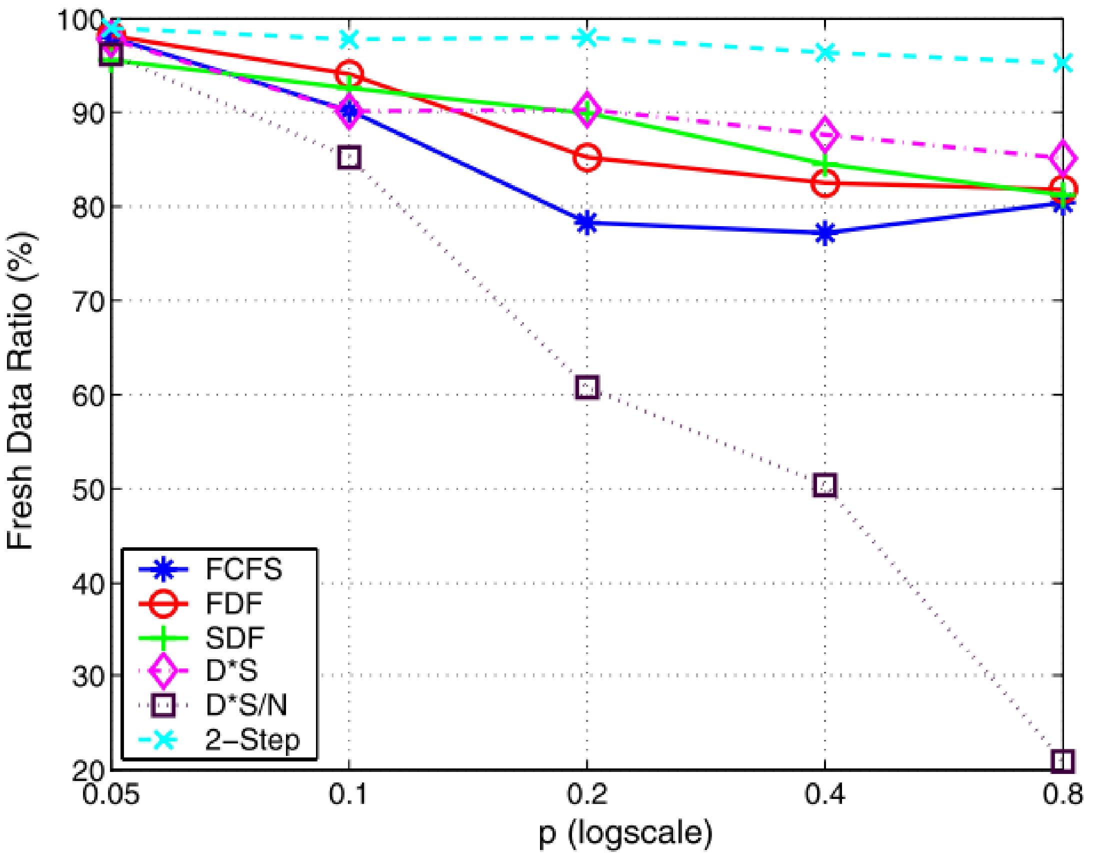
Effect of Workload



(a) Service Ratio

As workload increases, *D*S/N* can achieve the highest service ratio while its data quality degrades dramatically

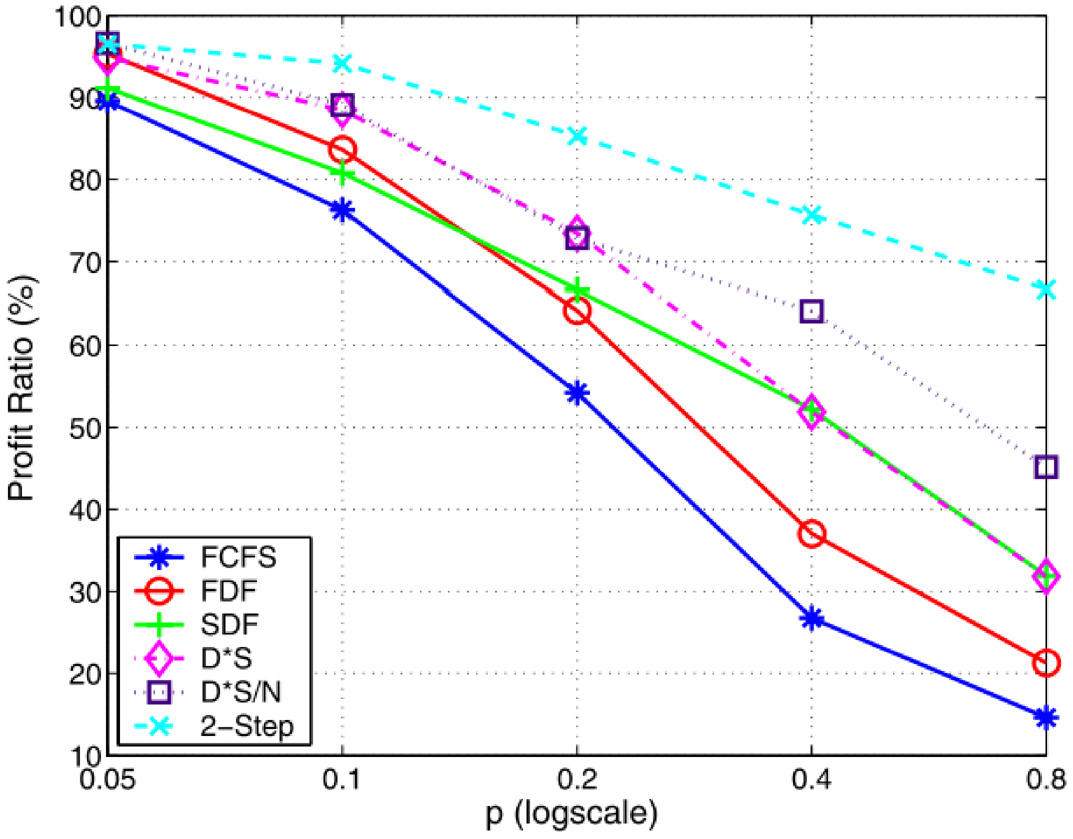
Effect of Workload



(b) Fresh Data Ratio

As workload increases, *D*S/N* can achieve the highest service ratio while its data quality degrades dramatically

Effect of Workload



(c) System Profit ($\alpha = 0.5$)

As workload increases, *D*S/N* can achieve the highest service ratio while its data quality degrades dramatically

Conclusion

- This paper proposed a basic scheduling scheme called *D*S* to consider both service deadline and data size when making scheduling decisions.
- To make use of the wireless broadcasting, this paper proposed a new scheduling scheme called *D*S/N* to serve multiple requests with a single broadcast.
- This paper also identified the effects of upload requests on data quality, and proposed a *Two-Step* scheduling scheme to provide a balance between serving download and update requests.