

Demand-based Network Planning for Large Scale Wireless Local Area Networks

Chutima Prommak, Joseph Kabara, Senior Member, and David Tipper, Senior Member

Abstract—A novel approach to the WLAN design problem is proposed that accounts for user population density in the service area, traffic demand characteristics and the physical structure of the service area. The proposed demand-based WLAN design technique results in a network that meets both the radio signal coverage requirement and the data rate capacity required to serve expected user traffic demand in the service region. The demand-based WLAN design model is formulated as a Constraint Satisfaction Problem (CSP). An efficient heuristic solution technique is developed to solve the CSP network design problem. The solution produces the number of access points required and the parameters of each access point, including location, channel assignment, and power level. We demonstrate applications of the demand-based WLAN design technique in various network design scenarios ranging from a single floor with small and large service areas to a multiple floor environment.

Index Terms—Network planning, Constraint Satisfaction Problem, Wireless Local Area Networks, Demand-based network planning

I. INTRODUCTION

WIRELESS local area networks (WLANs) are experiencing tremendous growth, providing untethered data networking capabilities [1, 2]. Their deployment has been facilitated by the availability of unlicensed frequency spectrum and inexpensive network equipment [3]. As WLAN-access devices become cheaper, smaller and more powerful, there has been phenomenal growth in the number of people who use WLAN services [1-4]. In designing WLANs, network designers should design a network that accommodates both growth of the user population and increased demand for services. However, most existing indoor wireless network design methods focus on radio signal coverage, which ensures only that an adequate signal strength

is maintained over the intended service area [5-20]. A new, demand-based WLAN design approach useful in the network design of large scale WLANs is proposed in this paper.

II. WLAN DESIGN MODEL

The task of demand-based WLAN design is to place a sufficient number of access points (APs) in a service area which may span multiple floors. The power level and frequency channel of an AP, together with the environment specific path loss and the antenna radiation pattern, determine the region (called Basic Service Area (BSA)) over which the AP can support traffic demand to/from wireless users. According to capacity analysis of the CSMA/CA protocol used in 802.11 WLANs, the capacity of an AP varies depending on the number of wireless users simultaneously transferring data through the AP [21]. As the number of wireless users actively transferring data through an AP increases, the effective AP capacity decreases [21]. Thus, the number of APs in a service area should be a function of the number of users and the characteristics of their traffic demand [22]. Due to the low cost of the APs, compared to the wireless devices with which they communicate, minimizing the number of the APs is unnecessary [23]. Thus, the WLAN design problem can be formulated as a Constraint Satisfaction Problem (CSP) which aims to determine the number of APs, identify their locations, assign to them power levels and frequency channels such that the resulting network satisfies the network design criteria described below.

A. Network Design Criteria

1) *Radio Signal Coverage Requirement*: A fundamental requirement for a wireless network is that it provide radio signal coverage over the target service area [24]. Radio receivers require a minimum radio signal level in order to access the network. As a measure of radio signal availability and coverage, the received signal strength and the signal to interference ratio (SIR) are considered in the design model. The received signal strength by wireless nodes must exceed the specified receiver sensitivity threshold. Additionally, the received signal strength from the serving AP must be sufficiently greater than the signal received from other APs operating on the same or overlapping frequency channels as specified by the SIR.

2) *User Data Rate Capacity Requirement*: As the user

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Chutima Prommak is with the School of Telecommunication Engineering, Suranaree University of Technology, Nakhon Ratchasima, 30000, Thailand, (e-mail: cprommak@mail.sis.pitt.edu).

Joseph Kabara is with the Department of Information Sciences and Telecommunications, University of Pittsburgh, Pittsburgh, PA 15260 USA. (phone: 412.624.9417, FAX: 412.624.2788, e-mail: jkabara@pitt.edu).

David Tipper is with the Department of Information Sciences and Telecommunications, University of Pittsburgh, Pittsburgh, PA 15260 USA. (e-mail: dtipper@mail.sis.pitt.edu).

population grows and multimedia applications requiring higher data rates spread the obtainable user data rate (link rate) becomes an essential concern in designing WLANs [5, 23]. Network trace studies [25-29] report that average obtainable user data rates does not depend merely on the number of wireless users existing in the service area, but also on the activity of wireless users in the network. Additionally, traffic volume in the network correlates with user behavior [25]. User behavior in turn correlates to the types of locations where users are situated and the major activities users typically pursue in those locations [25-29]. The following sections discuss the incorporation of information about characteristics of WLAN usage and traffic patterns into the design model.

B. Demand Node Representation for WLAN Design

The demand node concept used in facility location problems describes the geographic pattern of demand for retail goods and services [30]. The concept was extended to wide-area wireless network design to represent the distribution of expected network traffic in a service area [31, 32]. In designing WLANs a demand node represents an individual prospective wireless user in a service area. The definition allows a designer to describe precisely the potential number of wireless users and their locations, in order to appropriately place APs and assign users to the APs. In WLANs, users communicate through APs using the CSMA/CA protocol in which users compete for channel access and share AP capacity. Therefore, information about the number of users is required to calculate an average user data rate while information about user locations is needed to appropriately assign users to an AP based on an acceptable radio signal level.

Network trace studies characterized the usage of WLANs in various environments such as on university campuses [26, 27], in corporate office buildings [25], in academic buildings [28], and in a large auditorium [29]. Similarities exist in network usage characteristics among different network environments [25-29]. Traffic load at APs depends on users' level of data transfer activity in addition to the number of wireless users situated within the radio coverage area of APs. Network trace studies show a correlation between users' level of data transfer activity and locations where users are present [25-27, 29].

In the proposed WLAN design model, a user activity level, α_i parameter accounts for the correlation between network usage characteristics and user locations. α_i is the percentage of wireless users in a sub-area of type t who simultaneously transfer data through APs. We define three types of sub-areas: $t = \{1,2,3\}$ where 1 denotes private sub-areas, such as offices, 2 denotes public sub-areas for unscheduled activities, such as student lounges, and 3 denotes public sub-areas for schedule-based activities, such as classrooms. Active users participate in medium contention to gain access to a communication channel and share AP capacity. The remaining users $(1-\alpha_i)$ are

idle users who, although situated in a sub-area of type t , do not generate data transfer activity over the network at a particular time and therefore do not affect AP capacity [29]. An average user data rate requirement in sub-area of type t (R_t) imposes a desired link rate that should be available to active users in average.

C. Demand-based WLAN Design Model

The demand-based WLAN design problem is formulated as a Constraint Satisfaction Problem (CSP), with prescribed requirements for a finite number of variables with a given set of possible values (called domains) that can be assigned to the variables [51]. A constraint limits which tuples may form a solution.

Let $G = \{g_1, g_2, \dots, g_c\}$ denote a set of signal test points (STPs) representing locations for testing the received signal strength and the SIR level. Each STP g_h refers to a coordinate in three-dimensional space (x_h, y_h, z_h) , where z_h is the floor where g_h is located.

Let $U = \{d_1^t, d_2^t, \dots, d_m^t\}$ denote a set of demand nodes, where index t indicates the type of sub-area where demand node i is located. The position of demand node i within the service area is denoted by (x_i, y_i, z_i) , where (x_i, y_i) are the coordinates on floor z_i where d_i^t is located. The user activity level (α_i) and the average data rate requirement (R_i) specify the network usage characteristics for the demand node. The set of demand nodes together with the sub-area classification and parameters specifying network usage characteristics (α_i and R_i) are given as input to the design process.

The CSP for the demand-based WLAN design model is defined by the triple (V, D, C) , where

$V = \{n, p_j, f_j, d_{ij}^t, g_{hj}, (x_j, y_j, z_j)\}$ denotes a set of variables of the design problem

$D = \{D_n, D_p, D_f, D_d, D_g, D_{(x,y,z)}\}$ denotes a set of finite domains associated with each variable

$C = \{C1, C2, C3, C4, C5, C6, C7, C8, C9\}$ denotes a set of constraints

Let $A = \{ap_1, ap_2, \dots, ap_n\}$ denote a set of APs used in the service area, where n is the total number of APs required. Let $ac_j = \{p_j, f_j, (x_j, y_j, z_j)\}$ denote a set of parameters assigned to ap_j for $1 \leq j \leq n$, where p_j denotes the power level assigned to ap_j , f_j denotes the frequency channel assigned to ap_j , and (x_j, y_j, z_j) denotes the coordinate (x_j, y_j) on floor z_j where ap_j is located. d_{ij}^t is a user association binary variable that equals 1 if demand node $i \in U$ associates to $ap_j \in A$; 0 otherwise. g_{hj} is a signal availability binary variable that equals 1 if STP $h \in G$ can receive a signal from $ap_j \in A$; 0 otherwise.

D_n is a set of integer numbers, which are candidate for the number of APs used in the network. D_p is the set of candidate power levels for variable $p_j = \{P_1, P_2, \dots, P_{\max}\}$. D_f is the set of candidate frequency channels for variable $f_j = \{F_1, F_2, \dots, F_k\}$. D_d and D_g are $\{0, 1\}$ the domain of binary variable d_{ij}^t and g_{hj} ,

respectively. $D_{(x,y,z)}$ is the domain of variable (x_j, y_j, z_j) where $x_{min} < x_j < x_{max}$, $y_{min} < y_j < y_{max}$, and $z_j \in FLOOR = \{1^{st}, 2^{nd}, \dots, 1^{th}\}$.

Parameters in the design process are classified into static and dynamic parameters. Static parameters do not change during the design process because they depend solely on standard requirements and the characteristics of user activity in service area. Static parameters specifying the physical signal requirements (e.g., the received signal strength ($P_{Rthreshold}$) and the SIR level ($SIR_{threshold}$)), user profiles (e.g., the user activity level (α_i) and the average user data rate requirement (R_i)), adjacent channel interference between signals from overlapping channels (η_{jk}), and the data rate capacity of AP (C_j) that will be employed in the network. Dynamic parameters are recomputed each time a variable changes value during the design process. Dynamic variables include received signal strength ($P_{R_{ij}}$), interference level ($Intf_{ij}$), and average obtainable data rate (r_i^t).

The constraints in the CSP for the demand-based WLAN design model are:

$$\begin{aligned}
\text{C1: } & \sum_{\forall j \in A} d_{ij}^t = 1, \forall i \in U \\
\text{C2: } & d_{ij}^t (P_{R_{ij}} - P_{Rthreshold}) \geq 0, \forall i \in U, \forall j \in A \\
\text{C3: } & d_{ij}^t (P_{R_{ij}} - Intf_{ij} - SIR_{threshold}) \geq 0, \forall i \in U, \forall j \in A \\
\text{C4: } & r_i^t > R_i, \forall i \in U \\
\text{C5: } & \sum_{\forall j \in A} g_{hj} \geq 1, \forall h \in G \\
\text{C6: } & g_{hj} (P_{R_{hj}} - P_{Rthreshold}) \geq 0, \forall h \in G, \forall j \in A \\
\text{C7: } & g_{hj} (P_{R_{hj}} - Intf_{hj} - SIR_{threshold}) \geq 0, \forall h \in G, \forall j \in A \\
\text{C8: } & d_{ij}^t \in \{0, 1\}, \forall i \in U, \forall j \in A \\
\text{C9: } & g_{hj} \in \{0, 1\}, \forall h \in G, \forall j \in A
\end{aligned}$$

Constraints C1-C3 ensure that the prospective wireless users in the service area can connect to the WLAN. Satisfying C1-C3 simultaneously results in each demand node having adequate received signal strength and SIR levels such that wireless data transfer can take place. Constraint C1 requires that each wireless user associates to one and only one AP. The decision variable d_{ij}^t is equal to one if the received signal

strength that user i receives from the ap_j ($P_{R_{ij}}$ in dBm) and the SIR level with respect to the ap_j (the received signal strength ($P_{R_{ij}}$ in dBm) less the interference level ($Intf_{ij}$ in dBm)) meet the receiver sensitivity threshold ($P_{Rthreshold}$) and the SIR threshold ($SIR_{threshold}$) as specified by C2 and C3, respectively; d_{ij}^t is equal to zero otherwise.

Constraint C4 ensures that the average data rate available to wireless user i which is a type t user (r_i^t) is greater than the specified user data rate (R_i). The 802.11 capacity model and the user activity pattern correlated with the type of sub-areas where users locate are incorporated in this constraint to estimate the average data rate that the active wireless user can obtain [21, 33].

The set of constraints C5 – C7 ensure that the radio signal is available throughout the service region. To assess the signal quality in the service area, the received signal strength and the SIR level are tested at all signal test points (STPs). Constraint C5 specifies that each STP must be able to receive a signal from at least one AP. The decision variable g_{hj} is equal to one if the received signal strength at the STP h transmitted from the ap_j ($P_{R_{hj}}$ in dBm) and the SIR level with respect to the ap_j (i.e., $P_{R_{hj}} - Intf_{hj}$) meet the received sensitivity threshold ($P_{Rthreshold}$) and the SIR threshold ($SIR_{threshold}$) as specified by C6 and C7, respectively; g_{hj} is equal to zero otherwise.

Constraints C8 and C9 specify that variable d_{ij}^t and g_{hj} are binary $\{0, 1\}$ variables, respectively.

III. SOLUTION TECHNIQUE

Fig. 1 shows the framework of the heuristic solution technique. The core of the solution technique takes two inputs. The first input describes the physical properties of the service area (e.g., building size, location and composition of partitions, etc.) and the user traffic information (e.g., user location density, user activity level and required average data rates). The second input specifies models (functions) and parameters for fundamental calculations necessary to the solution technique, including the path loss model, the 3-D antenna radiation model, and the capacity model. The parameters include the necessary information to formulate and compute the constraints in the CSP (e.g., SIR threshold, received signal strength threshold, path loss exponent, etc.). The output specifies the number of APs required and their parameters, including location, power level, and frequency assignment.

The solution technique consists of five phases; the construction phase, the frequency channel assignment (FCA) phase, the constraint violation reduction (CVR) phase, the intensification phase and the add-AP phase. Fig. 1 shows the relationship between the phases. The first two phases (the construction and FCA phases) aim to generate a good starting configuration that provides an estimated number of APs and their initial parameters. The construction phase employs two heuristics: the Area Covering Heuristic (ACH) and the

Demand Clustering Heuristic (DCH). The ACH estimates the number of APs needed to provide radio signal coverage to the service area, while DCH places additional AP(s) in those parts of the service area where high traffic volume exists. Together, these two heuristics determine the initial locations and power levels of the APs. The FCA phase utilizes simulated annealing to determine the frequency channel assignments of the APs based on AP locations and power levels determined in the construction phase. The CVR phase evaluates the network configuration based on the set of constraints. If any design requirement constraint is violated, the CVR phase reduces the

constraint violations by adjusting the locations and power levels of the APs by using Tabu search. The CVR phase reassigns frequency channels by using the FCA simulated annealing method. If the CVR phase fails to produce a feasible network configuration satisfying all design constraints, the intensification phase revisits good candidate solutions recorded during the CVR phase and performs a repairing process for each revisited solution. After the intensification phase, if a feasible network configuration is still not found, the add-AP phase attempts to solve the problem by installing additional AP(s) in the service area.

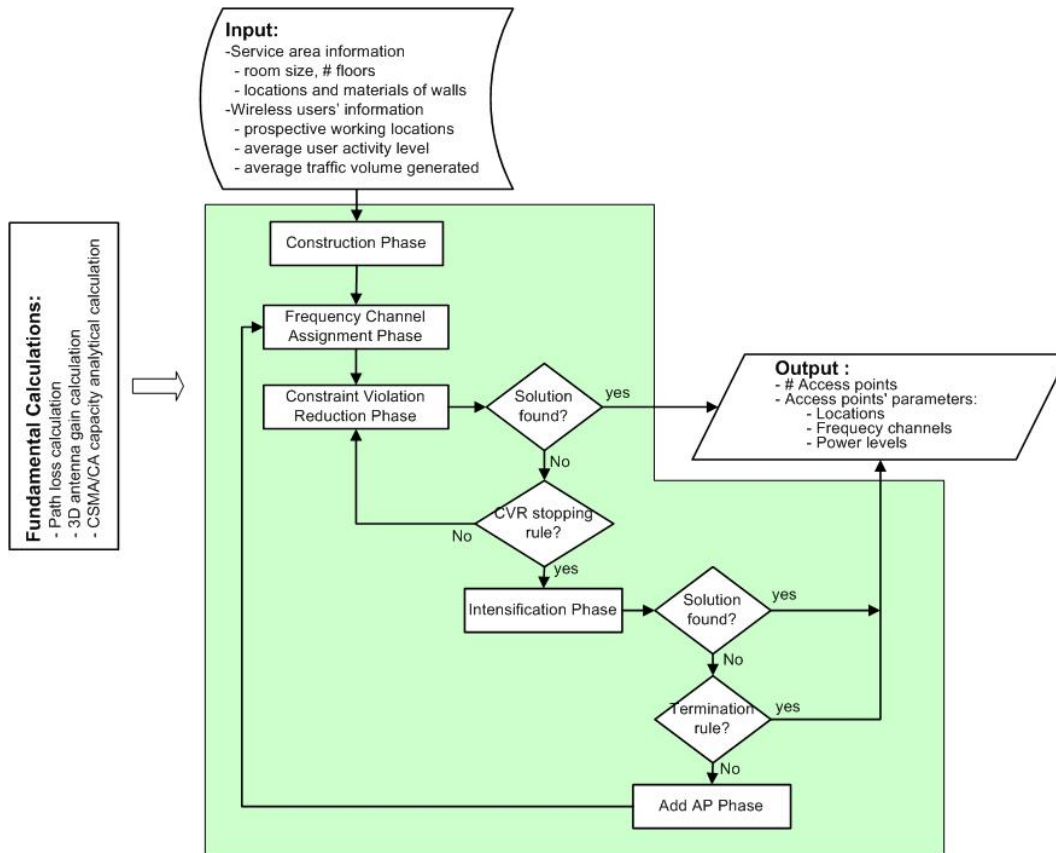


Fig. 1 Framework of the solution technique

IV. NUMERICAL RESULTS

Results from several WLAN design problems, ranging from a single floor WLAN design (section IV. A) to a multi-floor WLAN design (section IV. B), demonstrate the applicability of this technique.

A. Single Floor WLAN Designs

Numerical network design experiments were conducted for both small and large single-floor service areas. The small service area considered is the fourth floor of the School of Information Science building (SIS4) (dimension 33×21 meters), shown in Fig. 2a, while the large service

area is the first floor of the Hillman Library building (HL1) (dimension 66×75 meters), shown in Fig. 2b. Both buildings are located on the University of Pittsburgh campus. SIS4 resembles a typical floor plan of an academic building containing both public and private network usage areas. The public areas are used for both scheduled and unscheduled activities. Scheduled activities occur in classrooms (rooms 403, 404, 405, 406 and 411) and laboratories (rooms 409 and 410), while unscheduled activities occur in the student lounge (room 401). The private areas of SIS4 are graduate student offices (rooms 402, 407, and 410). HL1 also contains both public and private usage areas. The public areas are the study areas,

while the private areas are library staff offices.

Demand node distributions were created from site surveys and information from the facility staff in each location. Figure 2 shows the demand node distributions representing prospective wireless users in the service areas. The symbol \bullet represents demand nodes located in public areas for scheduled activities, the symbol \blacktriangle represents demand nodes located in public areas for unscheduled activities, and the symbol \star represents demand nodes located in private areas. User activity levels corresponding to each sub-area type are based on studies showing that users in private sub-areas are the most active network users, followed by users in the public areas for unscheduled activities and then users of public areas for schedule-based activities [25, 26, 29]. Similarly, the average user data rates are taken from observed network usage characteristics [25,

26, 29]. Table I summarizes the network usage characteristics.

Table II summarizes the Input parameters of the network design problem. In these examples the variables reflect the 802.11b specification. The log distance path loss model and the omnidirectional antenna (halfwave dipole) with a G_{AZ} gain of 2.5 dB are used to estimate the radio propagation characteristics in the service area. The design aims for 95% coverage availability at the edge of AP coverage areas [24]. In this case, a fading margin of 5.75 dB is applied in the signal coverage calculation.

In these examples the service area is divided into grids of size $1\text{m} \times 1\text{m}$. The grid points represent possible locations for APs and specify the Signal Test Points (STPs). Fig. 3 illustrates STPs in the SIS4 service area.

TABLE I
NETWORK USAGE CHARACTERISTICS

Sub-areas	User activity level	Average user data rate (Kbps)
Type 1: Private sub-areas (e.g., graduate student and library staff offices)	$\alpha_1 = 0.50$	$R_1 = 460$
Type 2: Public sub-areas for unscheduled activities (e.g., library study areas, student lounge)	$\alpha_2 = 0.40$	$R_2 = 260$
Type 3: Public sub-areas for schedule-based activities (e.g., classrooms, laboratories)	$\alpha_3 = 0.35$	$R_3 = 80$

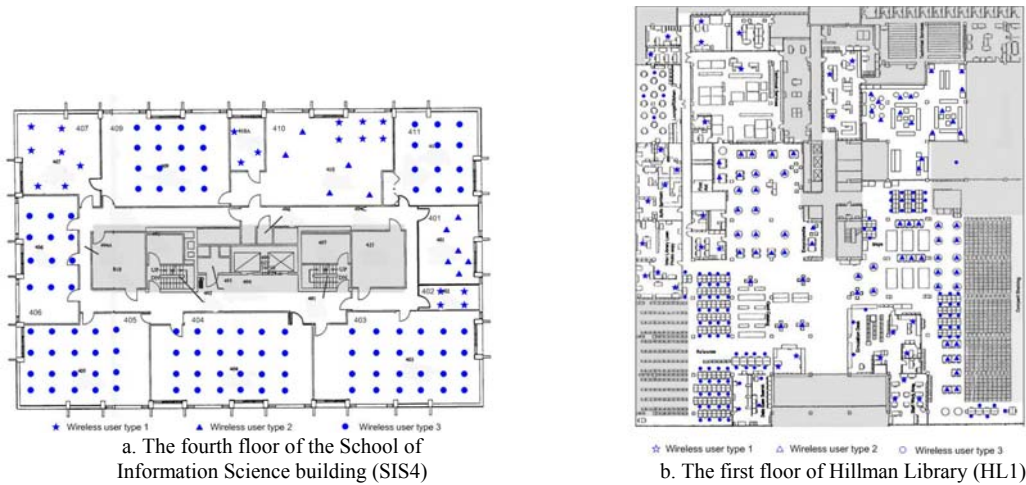


Fig. 2 Floor plans and demand node distribution of SIS4 and HL1

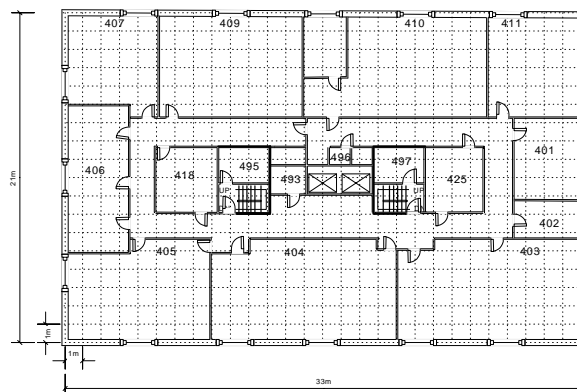


Fig. 3 Grid point resolution of the small service area (SIS4)

TABLE II
SUMMARY OF PARAMETERS USED IN WLAN DESIGN

Parameter	Definition	Value
Domains of Variables:		
D_p	Set of candidate power levels for variable p_j	{0, 7, 13, 15, 17, 20, 24} in dBm [34]
D_f	Set of candidate frequency channels for variable f_j	{2.412, 2.437, 2.462} in GHz [34]
D_d	Domain of binary variable d_{ij}^t	{0, 1}
D_g	Domain of binary variable g_{bj}	{0, 1}
$D_{(x,y)}$	Domain of variable (x_j, y_j) for $\forall j \in A$ (in meter)	For SIS4, $0 < x_j < 33, 0 < y_j < 21$ For HL1, $0 < x_j < 66, 0 < y_j < 75$
Static Parameters:		
α_t	User active level defines percentage of wireless users in sub-area type t that are engaged in data transfer activities (i.e., participating in channel contention and sharing AP capacity)	See Table I
R_t	Average user data rate requirement in sub-area type t	
$P_{Rthreshold}$	Received sensitivity threshold	-80 dBm [35]
$SIR_{threshold}$	Signal to interference ratio threshold	10 dB [35]
C_j	Data rate capacity of the ap_j for $\forall j \in A$	11 Kbps [35]
Path loss Parameters:		
d_0	Reference distance d_0	1 meter [36]
n	Path loss exponent	3.3 [37]
δ	Standard deviation representing shadow fading	3.5 dB [38]
Antenna Parameters:		
G_{AZ}	Antenna gain (peak directivity)	2.5 dB [39]

Note:

- The frequencies 2.412, 2.437, and 2.462 GHz are denoted by channels number 1, 6, and 11, respectively.
- The transmit power of 0, 7, 13, 15, 17, 20 and 24 dBm are denoted by power levels 0, 1, 2, 3, 4, 5, and 6, respectively.

We applied the proposed demand-based WLAN design model to the SIS4 and HL1 network service areas. Fig. 4 and 5 depict the resulting WLAN configurations for SIS4 and HL1, respectively.

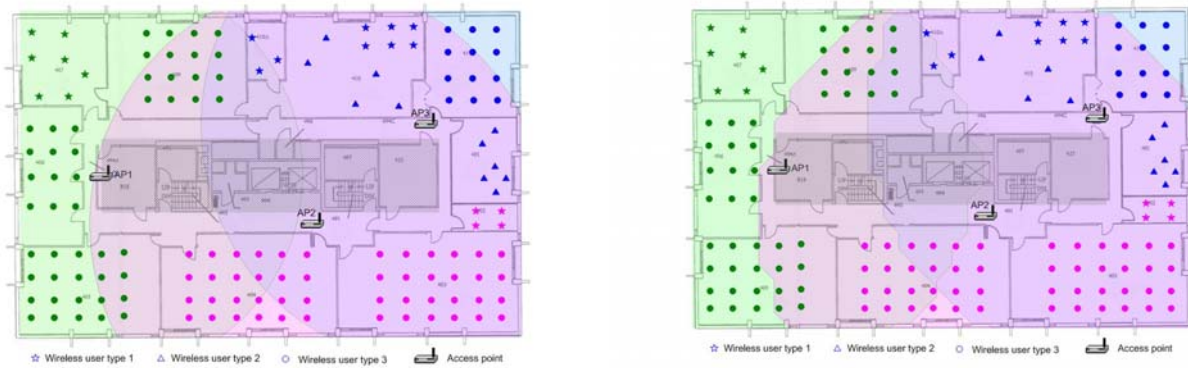
Fig. 4 shows the SIS4 service area, where demand based network planning resulted in a network configuration using three APs. Based on the analytical models for CSMA/CA capacity [33], the obtained network configuration satisfies average data rate requirements to wireless users in the service area. Fig. 5 depicts the HL1 service area, and a network configuration utilizing seven APs. The resulting network configuration assigned the APs' frequency channels, power levels and locations so that interference in the service area is avoided and the specified SIR threshold is met.

Fig. 4a and 5a show contour plots of the APs' signal coverage regions, representing the areas for which the received signal strength from a particular AP is at least equal to the receiver sensitivity level. Fig. 4b and 5b show contour plots of the APs' basic service areas, representing the area around the APs in which the SIR level is at least equal to the specified SIR threshold. Within such an area, the signal quality is good enough to allow communication between a wireless terminal and a particular AP. The shading of the contour plot figures corresponds to the frequency channels assigned to APs. In this case, channels 1, 6, and 11 are indicated by shades of green, pink, and blue, respectively. Demand nodes are colored to match their assigned AP. Fig. 4c and 5c provide the APs' parameters, including location, frequency channel, and power level.

B. Multi-floor WLAN Designs

A WLAN's service area may include some rooms on a single floor, an entire floor or even multiple floors. APs located on adjacent floors may interfere with each other if the design does not coordinate the AP placement, frequency assignment, and power level assignment. Consider the design of a service area aiming to cover the fourth and fifth floors (SIS4 and SIS5) of the School of Information Science building as shown in Fig. 6. SIS4 was described in the previous example and similarly, SIS5 also has a large central structure with the same components as that of SIS4. Around the core are administrative offices, conference rooms, and classrooms. The expected wireless users on these two floors are represented by the demand node distribution map shown in Fig. 6. Wireless users located in private office spaces can be identified by faculty and staff desks, whereas prospective users in classrooms and laboratories can be estimated from the available seats in the room. The network usage characteristics of prospective wireless users used in this section are the same as those shown in Table I.

The demand-based design method results in a network employing five APs. Based on traffic demand, three of the APs (AP1, AP2, and AP3) are located on the fourth floor. Two APs (AP4 and AP5) are located on the fifth floor. Fig. 7 depicts the signal coverage on each floor. Fig. 7a and 7b show signal coverage on the floor where the APs are located; Fig. 7a showing coverage on the fourth floor and Fig. 7b showing coverage on the fifth floor. Again the BSA



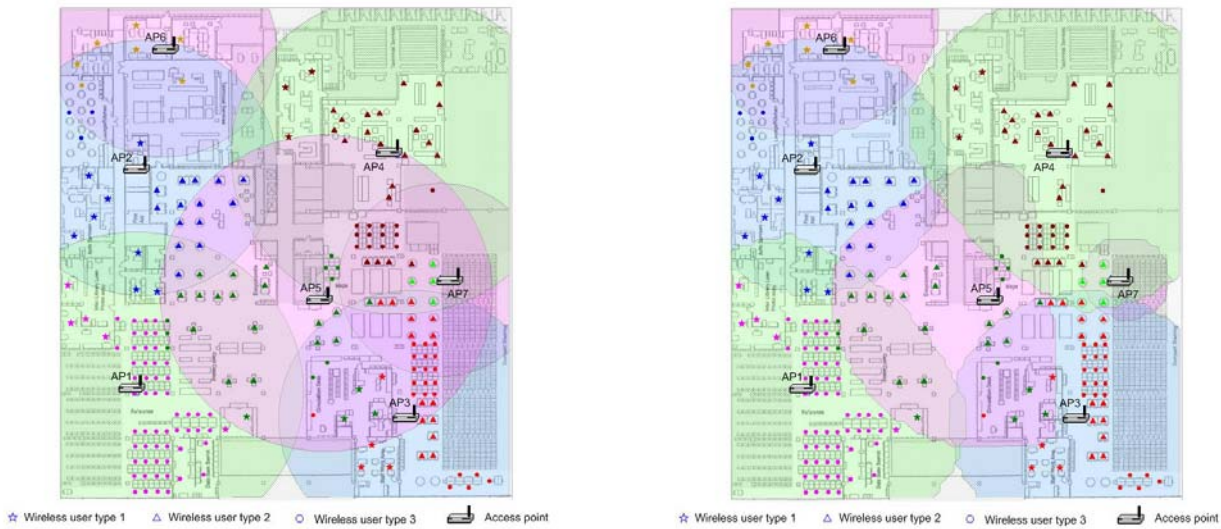
a. Contour plot of APs' signal coverage area

b. Contour plot of APs' basic service area

c.

AP	Location	Frequency Channel	Power level	Colors represent user association to AP
1	(6.0,10.0)	1	6	Green
2	(19.0,7.0)	6	6	Magenta
3	(26.0,13.0)	11	6	Blue

Fig. 4 WLAN network configuration for a small service area (SIS4)



a. Contour plot of APs' signal coverage area

b. Contour plot of APs' basic service area

c.

AP	Location	Frequency Channel	Power level	Colors represent user association to AP
1	(18.0,13.0)	11	5	Magenta
2	(15.0,43.0)	1	5	Blue
3	(51.0,10.0)	11	4	Red
4	(40.0,50.0)	1	5	Green
5	(10.0,20.0)	6	5	Yellow
6	(16.0,52.0)	11	5	Orange
7	(35.0,28.0)	6	6	White
8	(49.0,26.0)	1	4	Light Green

Fig. 5 WLAN network configuration for a large service area (HL1)

Are shaded based on channel with channels 1, 6, and 11 are indicated by shades of green, pink, and blue, respectively. Fig. 7c presents signal coverage from two APs located on the fifth floor to the area of the fourth floor while Fig. 7d presents signal coverage from three APs located on the fourth floor to the area on the fifth floor.

The process of assigning frequency channels in the heuristic solution technique coordinates the channels assigned to APs on different floors to limit interference in the network. Fig. 8a and 8b depicts overall signal coverage on each floor. The signal penetrating from each floor is superimposed on the contour plot of the other floor. The demand node assignment is represented by different colors as listed in Fig. 8c. For example, the demand node assigned to AP1 is green, and the demand node assigned to AP2 is blue. We can see that the blue demand nodes on the fifth floor are assigned to AP2 on the fourth floor and that the pink demand nodes on the fourth floor are assigned to AP4 on the fifth floor.

V. CONCLUSION

Existing WLAN design methods focus on providing radio coverage in the service area. However as WLANs become more widespread and the price of notebook and handheld computers drops, the number of wireless users and the expected increase in network traffic must be considered in the network design process. Radio coverage design methods are insufficient and inefficient methods for designing networks for WLAN environments with high traffic demand. The proposed WLAN design approach and heuristic to solution results in network designs capable of support various traffic demand requirements. Experimental results show that the technique can be applied to sparsely populated spaces, large densely populated spaces and multi-floor designs. In each case the result is a network that satisfies the constraints, and although the constraint satisfaction formulation does not require it, the designs do not use an excessive number of APs.

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Fig. 6 Floor plans of the fourth and fifth floors of the School of Information Science building

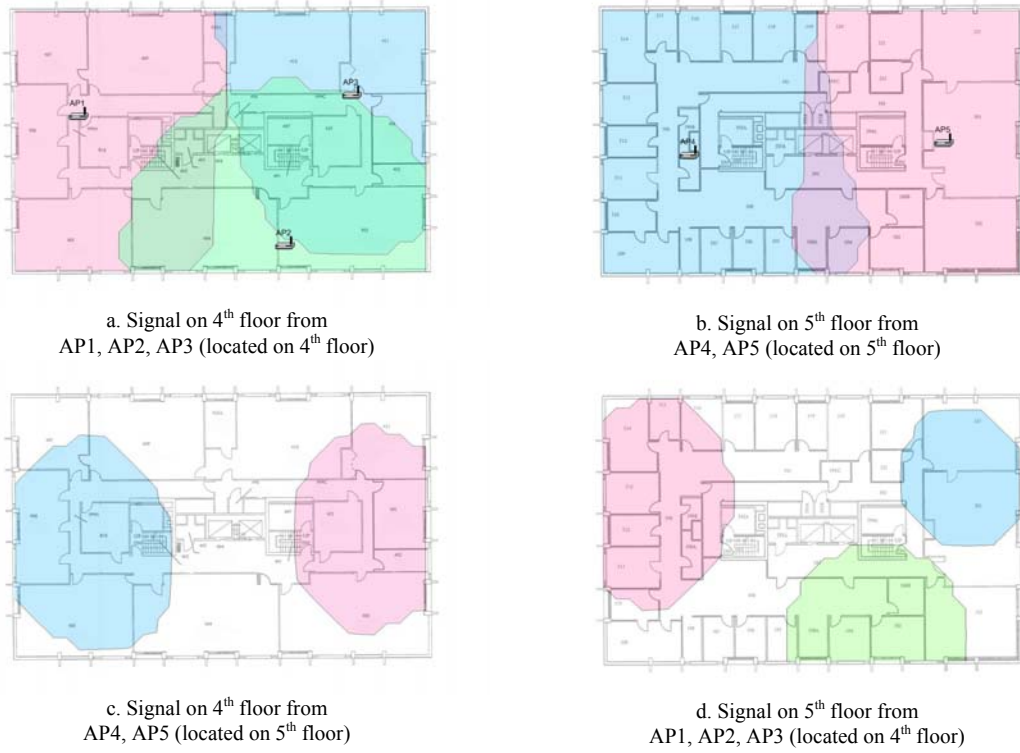
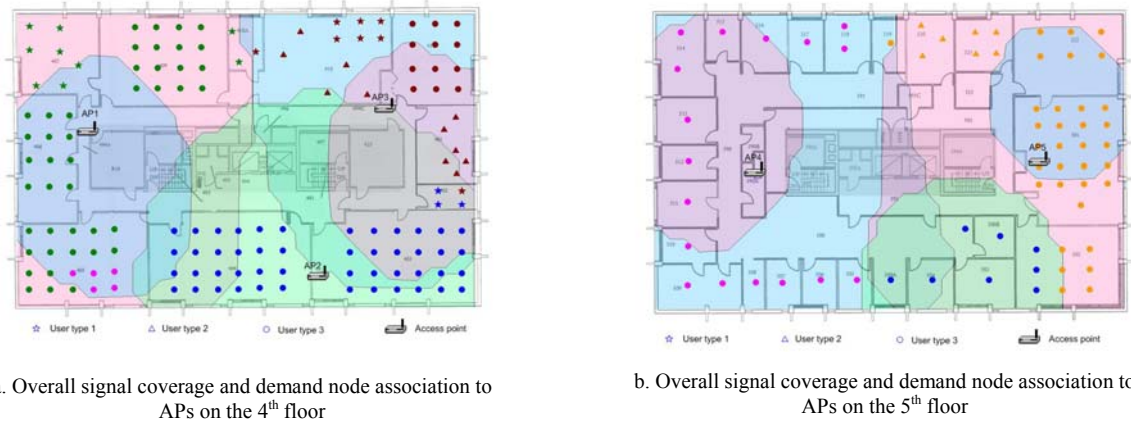


Fig. 7 Signal coverage from APs located on different floors



c.

AP	Location	Floor number	Frequency channel	Power level	Colors represent user association to AP
1	(5.0,12.0)	4	11	5	Green
2	(21.0,2.0)	4	1	6	Blue
3	(26.0,13.0)	4	6	5	Red
4	(7.0,9.0)	5	6	6	Magenta
5	(26.0,10.0)	5	11	6	Orange

Fig. 8 WLAN configuration of the 4th and 5th floors of the SIS building

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