



SPREADSHEETS *in* EDUCATION

Bond University

Volume 12 | Issue 1 | 2019

Simulating CDMA Data Communication Protocol Using Sheetlet-based e-Learning Object

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Simulating CDMA Data Communication Protocol Using Sheetlet-based e-Learning Object

Abstract

This paper presents an approach that uses interactive spreadsheet features and computer graphics to implement a learning object for data communication and networking. This learning object simulates the code-division multiple access multiple access data communication protocol. The model that we designed and implemented uses sheetlets that are spreadsheet-based and utilizes its features. Moreover, advanced spreadsheet tools and features, such as imagery and chart integration, hyperlinks, conditional structures and formatting, built-in functions, to simulate scientific notions that are taught to undergraduates were exploited in the built model. Specifically, three sheetlets for modelling and simulating this networking protocol were fully designed and implemented. The features of these models are rapidity of implementation compared to other designing tools. Furthermore, the designing technique is characterized by simplicity, flexibility, and affordability. The developed sheetlet learning object is also featured by the power of reusability and transparency of integration in e-learning environment. It can work as a practical hands-on experience for the learners of the subject matter. The technique we applied for the design and implementation of the learning objects for computer networking protocols could be extended to other fields. It can be used as a framework for structuring similar e-models related to many disciplines in education, business, science, and technology. These models can assist instructors to develop more learning objects that in turn will help students for improved insight and exploration of the related educational concepts. In addition, the learners can use the developed educational models without instructor supervision in self-education or e-learning settings.

Keywords: CDMA protocol, computer networks, data communication, spreadsheet, sheetlet, learning object, e-learning, educational technologies.

1. Introduction

In science and technology educational fields, students need to gain practical skills beside the theoretical knowledge. These skills are acquired through the availability of equipment to perform experiments on real scenarios. Specifically, in the teaching of data communication, the main problem that arises is the costly and limited number of devices the students can practice on in the labs [1]. Technology-based realization, visualization and simulation tools can overcome these constraints. They offer an excellent alternative to the costly and limited labs.

Technology-based instruction is very vital in college education and has become increasingly ubiquitous in contemporary e-learning systems. It assists the students to visualize real experimentations effectively and in short timings. This trend of technology employment saves effort that can be dedicated towards more exploration of the educational topic matter. Moreover, technology-based education attracts students' interest and boosts their motivation during the learning process.

Concepts of a computational nature can be made more graspable to learners by using modern computer-based technologies. One of the common tools for simulating and realization those concepts is the implementation of computer applications written using either high-level programming languages, such as C#, C++, and Java, or by using some sophisticated packages, such as MATLAB. This design approach requires availability of advanced software packages, familiarity with the interfacing techniques, and dedicating resources to achieve acceptable level of realization.

Spreadsheets offer very efficient and powerful computing alternative tools for flexible use and rapid implementation and realization of the computational tasks. Mainly, they are used to store and manipulate data, process mathematical and logical functions, and visualize input and output in numerous formats and styles.

Computational spreadsheets can be used as implementation computing tools for the topic or concept of interest. Spreadsheet-based implementations assist students in learning and offer them the ability to attempt, explore, investigate, and test various cases and settings related to a designated problem. They also can effectively improve the attitudes of students toward learning [2]. Spreadsheets could be used as a motivation and empowering tool for making inferences by enabling learners to investigate an open-ended problem, and to share their results out of the spreadsheets [3].

The use of learning objects supported by spreadsheet-based sheetlets, which are supplemented with computer graphics and illustrations, can be considered as an effective and powerful approach to be utilized in various educational disciplines for introducing instructional notions to the learners. They offer tools and tactics to illustrate the temporal changes in an instructional concept. The tools can be used to support instructors to establish effective instructional topic matters.

The purpose of this paper is to illustrate an approach of building learning objects based on sheetlets to teach and learn data communication and networking concepts and protocols. It also reveals a method for tracking the data transmission mechanism related to the computer communication. Although there are many characteristics of other designing software packages and tools that are superior to the sheetlet-based

designs, or they are favoured by some designers, but the widespread, user-friendliness, and supportability of the spreadsheets makes the development based on spreadsheets to be more common and desirable. The technique of modelling and implementing systems and problems using sheetlets can be achieved by instructors who are either inexpert with the implementations using complex tools and techniques, or by using sophisticated software packages.

2. Related Work

The learning of data communication and networking requires the learners to study, explore and analyse data transmission protocols. This task can be achieved by writing computer applications using high-level programming languages. Generally, most of the students are faced with the complication of realization due to the burden of design and implementation. In most of the cases, the realizations are implemented as command line interface (CLI) application, in which the interaction is limited to entering inputs and analysing outputs. Furthermore, for the students, the design and implementation of simulators using visualizations and graphical user interface (GUI) are even more resource hungry than CLI designs.

Spreadsheets have been used for a long period of time in various educational pedagogies. Their widespread use makes them attractive in the educational community; specifically, in tertiary education. Their numerous built-in tools and sophisticated capabilities make them a reliable means to model and simulate concepts and problems.

The exploitation of spreadsheets in education have been introduced in many educational and scientific disciplines. For example, they are used in teaching simulation [4], as a simulation tool for solving probability problems and statistics [5], and [6], and as a tool for simulating steam power plants [7]. One article illustrated the use of the spreadsheets in the processes of data encryption and decryption [8]. Still another paper illustrated leveraging spreadsheets in teaching probability and statistics [6], and [9]. One more article showed the use of spreadsheets to teach signal detection theory [10].

Spreadsheets have been leveraged in wide range applications. For example, engineering and technology applications [11], [12], and [13], engineering education [14], teaching computational thinking [15], teaching chemistry concepts [16], teaching and learning pipe networks analysis [17], and many more. Additionally, spreadsheet-based knowledge systems have been implemented [18]. The use of spreadsheets has been extended to enhance learning for undergraduates [2], and to introduce practical applications to undergraduate college students [19].

There are many computer science simulators that have been implemented for educational purposes. In general, using simulation tools can add more insight into aspects of computer science concepts that cannot be easily learned in the traditional laboratories [20]. Specifically, computer networking simulators are researched and developed for experimental learning and research to overcome lack of availability of physical networking equipment. There are several networking and data communication simulators that are available either as an open-source or commercial

software packages [20]. For example, a simulator for experimental teaching to overcome the limitations of the real network equipment resources [21], and web-based simulation and visualization tool for computer networks [22], have been developed. Specifically, for the CDMA data communication protocol, there are some simulators that have implemented this networking protocol using SCILAB [23], and MATLAB [24] software packages.

3. Learning Objects

A learning object is considered as a small building block in a topic structure. It is a collection of information and/or practice entities that are all integrated to reinforce a single educational objective. It plays a significant role in the applied experience of the learners. The Institute of Electrical and Electronics Engineers (IEEE) defines a learning object as "any entity, digital or non-digital, that may be used for learning, education or training" [25].

Adopting learning objects in education provides the students a chance for further discovery of the instructional concepts on their own. The use of dynamic learning objects instead of static learning units throughout the learning process eliminates the need for supplementary explanations and/or use of marking illustrations, so that displays can be clearer and less cluttered. Moreover, the use of learning objects in the learning context can make the topic matter to be attractive and intuitively perceived.

In this paper, we demonstrate the design and implementation of spreadsheet-based, particularly sheetlets, digital learning objects for teaching and learning data communication and networking protocols.

4. Spreadsheets

Spreadsheets are very powerful modelling and simulation tools that can be used to realize, explore and analyse computational tasks. For example, it can be used in the learning of mathematics using the offered development environments with which interactive applications with graphical components can be built and implemented [26], and [27]. Recent spreadsheet packages are equipped with sophisticated functions and tools. The utilization of those built-in functions reduces the load of implementation, testing, and debugging required by the programming-based designs. In turn, this utilization saves the time and effort of design, verification, and validation stages. Another powerful spreadsheet feature is the capability of representing data using assorted styles of charts. This feature enhances displaying and examining relations among data sets. It also facilitates representing output results with the cost of few fingertip keystrokes. Tools and functions, such as conditions, data sorting and filtering, linking, formatting, and many others, simplify implementing powerful and flexible computational forms that can be utilized in many educational and training applications and fields, specifically, e-learning, e-training, and e-teaching.

5. Sheetlets

An electronic sheetlet (e-sheetlet) is a small and more controlled computational sheet that has look and feel design property. It inherits the characteristics and structure of a spreadsheet. Sheetlets can contain data of various types. They can be formulated to compute functions and complex computations. The main feature of a sheetlet is its size compactness compared to a full spreadsheet that consists of millions of data cells. Furthermore, sheetlet can make the visualization of the designed model for the instructional topic to be more intuitive and obvious, as well as, less distracting and less cluttered.

Visuals, such as pictures and computer graphics, can be integrated in sheetlet-based designs. The use of these objects enhances the look-and-feel user interface for the educational topic or task. It makes the final designed learning object to be more informative, attractive, and resembles the visualization of the actual situations.

Due to their design flexibility and features, sheetlets can be used to implement models to be utilized to perform analysis of networking protocols. These models offer hands-on experience and further insight drill to the learners. The models also save time of designing and programming stages for the realization. The efforts can be dedicated towards focusing and investigating the topic matter. Moreover, efforts can be dedicated to the higher-order thinking skills to the related topic rather than towards the programming and designing issues. These sheetlets can give the learner the look and feel of the topic matter, instead of just only data processing modules.

The design of a sheetlet starts by using a blank spreadsheet that consists of millions of cells. Then, the borders of the cells are set to invisible. A contrast is made for designated cells to signify them as input and output textboxes. Next, text labels are added in order to assist the learner knowing the different textboxes. Afterwards, graphical objects are integrated, as they enhance the look of the learning object and make it more intuitive. Next, controls, such as radio buttons, spin buttons, scroll bars, ... etc, are incorporated in the design of a sheetlet. The properties of the controls are set and programmed to be linked to the associated components of the sheetlet for accurate operation and functioning. Finally, the sheetlet design is protected, so the users can only interact through the input textboxes. Figure 1 summarizes the steps of the sheetlet design.



Figure 1: Sheetlet design.

6. CDMA Data Communication Protocol

In multiple access data communication, computer stations are connected using a shared communication link. In the case of data transmission among stations, signals sent by different stations may interfere with each other due to the use of the shared medium. In order to avoid the problem of interference, a network protocol must be enforced.

There are many protocols for data transmission. One of the essential protocols taught to college level students in data communication and networking is called code-division multiple access (CDMA) channelization protocol [28], [29], [30]. It belongs to the family of channel partitioning protocols. CDMA is a networking access technique in which the available transmission bandwidth of a communication link is shared among stations using different codes. Currently, it is the prevalent protocol in wireless local area networks (LANs) and cellular technologies [29].

6.1. Chip Codes

CDMA networking protocol is based on coding theory, where each station in the network range is assigned a special code, which is a sequence of numbers called a chip. The chips must be orthogonal sequences. Orthogonality means that the inner product of two different codes is 0, and the inner product of the same code is n , where n is the number of stations in the network.

Walsh codes are the most common orthogonal codes used in CDMA applications [28], [29], [30]. A set of Walsh codes of length n is a matrix of size $n \times n$. Each row in the matrix represents one code sequence, so there are n codes, each of length n . The Walsh matrix is defined recursively as follows:

$$W_1 = [+1] \quad (1)$$

$$W_{2n} = \begin{bmatrix} W_n & W_n \\ W_n & \overline{W_n} \end{bmatrix} \quad (2)$$

where n is the dimension of the matrix, and the overscore on the lower left corner term of the matrix denotes the logical negation of the bits. The Walsh matrix satisfies the property that every code sequence is orthogonal.

6.2. Data Representation

A station can either be in a transmission state, or idle. In the transmission state, if a station sends digital data signal, it can be either a 0 bit or a 1 bit. When a station is idle, it sends no signal. The data bits to be transmitted are encoded at the transmitting host. The rules for representing data in the three cases are as follows:

$$d = \begin{cases} -1 & \text{if station sends 0} \\ +1 & \text{if station sends 1} \\ 0 & \text{if station is idle} \end{cases} \quad (3)$$

where d is a data bit to be transmitted.

These rules are applied to all data bits before the transmission.

6.3. Data Encoding

Assume a set n of connected stations in the network range and represented by

$$S_1, S_2, \dots, S_n \quad (4)$$

A sending station S multiplies the data to be transmitted (d_s) by the station's chip code C_s , to get encoded data

$$\mathbf{d}_e = \mathbf{d}_s \cdot \mathbf{C}_s \quad (5)$$

where \mathbf{d}_e is the encoded data

This operation is repeated for all the set of stations in the transmitting range to output one term per station. All the transmitting stations deliver their encoded signals to the common link. The encoded data that is transmitted on the channel is the sum of the all terms delivered by the transmitting stations, and it is expressed as

$$\mathbf{D} = \sum_{i=1}^n \mathbf{d}_i \cdot \mathbf{C}_i \quad (6)$$

where \mathbf{D} is the overall channel coded data.

The coded data on the shared channel is received by all the stations connected in the network transmission range.

6.4. Data Decoding

During data transmission, a station receives coded data from another station over the shared communication channel. To recover the original data delivered by a sender station x , the received coded data need to be decoded. The station that receives data from one station on the shared communication link multiplies the channel encoded data by the chip code of the sender station \mathbf{C}_x . This operation is expressed as

$$\mathbf{d}_x = \mathbf{C}_x \cdot \mathbf{D} \quad (7)$$

where \mathbf{d}_x is the decoded data received by the receiver station.

Substituting equation (6) into equation (7) leads to

$$\mathbf{d}_x = \mathbf{C}_s \cdot \sum_{i=1}^n \mathbf{d}_i \cdot \mathbf{C}_i \quad (8)$$

Equation (8) can be rewritten as

$$\mathbf{d}_x = \sum_{i=1}^n \mathbf{C}_s \cdot \mathbf{C}_i \cdot \mathbf{d}_i \quad (9)$$

This expansion of equation (9) can be written as

$$\mathbf{d}_x = \mathbf{C}_s \cdot \mathbf{C}_1 \cdot \mathbf{d}_1 + \mathbf{C}_s \cdot \mathbf{C}_2 \cdot \mathbf{d}_2 + \cdots + \mathbf{C}_s \cdot \mathbf{C}_n \cdot \mathbf{d}_n \quad (10)$$

Each term of equation (10) contains one inner product, that is, the product of two codes. Let \mathbf{p} represents the inner product of two codes \mathbf{C}_i and \mathbf{C}_j . This can be expressed as

$$\mathbf{p} = \mathbf{C}_i \cdot \mathbf{C}_j \quad (11)$$

Using the properties of orthogonality [28], the inner product

$$\mathbf{p} = \begin{cases} \mathbf{n} & \text{if } i = j \\ \mathbf{0} & \text{if } i \neq j \end{cases} \quad (12)$$

where \mathbf{n} is the number of elements in one code.

Applying the orthogonality properties, all the terms of equation (10) are equal to zero, except one term in which the indices of the codes are equal [28].

Let us assume that the inner product of the similar codes appears in the k^{th} term of equation (10). Then, all the terms of equation (10) will be set to zero except the k^{th} term.

This will result in the following

$$\mathbf{d}_x = \mathbf{C}_s \cdot \mathbf{C}_k \cdot \mathbf{d}_k \quad (13)$$

where \mathbf{C}_s and \mathbf{C}_k are similar codes.

Using relations (11) and (12), equation (13) can be written as

$$\mathbf{d}_x = \mathbf{n} \cdot \mathbf{d}_k \quad (14)$$

This term must be divided by \mathbf{n} to get the original data sent by a sender station

$$\mathbf{d}_k = \mathbf{d}_x / \mathbf{n} \quad (15)$$

7. Design Methodology

Several elements are integrated in the in the design and implementation of the models for the CDMA protocol learning object (CDMALO). These elements are categorized as graphic, textbox, control or label. They are used for the purposes of display data, select options, track flow, input data, output data, and legend. Table 1 lists these elements and their intended use.

Table 1: Elements used in the sheetlet-based CDMALO.

Element	Category	Use
Input textbox	open cell	enter user input
Output textbox	locked cell	display output data
Computer station	graphic icon	display sent-received data
Cable	graphic icon	display link signals
Radio buttons	control	select sending/receiving station
Checkbox button	control	Probing data signals
Cube box	graphic icon	represent data
Arrows	graphic lines	track data flow
Label	legend	explanatory text

The design approach of a computational sheetlet involves several stages. Figure 2 shows a block diagram of a proposed design approach. In the next text these stages will be highlighted briefly.

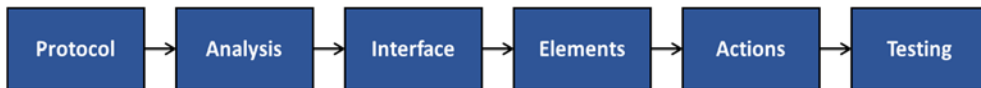


Figure 2: Sheetlet-based learning object design model for CDMALO.

The approach starts considering a certain networking protocol. Then, analysing the protocol to find out all the related inputs, mathematical relations, and outputs. The protocol must be well-analysed to provide a precise model, which is consequently converted into a sheetlet-based model that consists a sequence of structure

components and actions. Mostly, computations include simple or complicated formulas. In several cases, formulas are either entered directly into the sheetlet cells, or, in some cases, written in Visual Basic for Application (VBA) as subroutines which will be called in the case of use.

The next step is to design an interface of the learning object. Elements, such as controls and graphics are added to the learning object. These components will support the clarification and the use of the topic matter to the learners. Control elements such as command-buttons, radio-buttons, checkboxes are incorporated to allow user interaction with the learning object. They offer more flexibility and ease when using the developed sheetlet-based learning object. The controls require programming and linking with the appropriate elements for accurate operation. The insertion of graphics enhances the user interface. It can make the design more attractive, informative and standalone.

Next, actions will take place in terms of mathematical computations and animations. Although sheetlet-based animations are limited compared with other dedicated software packages, they can be achieved by applying several effects such as colour toggling, data and labels changes. Actions are applied wisely in accordance with the mechanism of the networking protocol.

The implemented sheetlet-based learning object can be integrated for use in many educational environments or it might probably be reused for functioning with other learning objects. The accurate functioning must be verified to overcome any confusion that may arise in the final deliverables. A thoroughly testing procedure must be applied to ensure accurate and precise operation of the overall produced learning object. In case of any operational inconsistency, the design stages must be revisited.

The designing methodology was used to implement several sheetlet-based computational learning objects. For the purpose of this paper, the following subsections sheetlet-based learning object that were designed and implemented for the CDMA networking protocol will be highlighted.

8. CDMA Learning Object

To facilitate the task of learning and exploring the CDMA shared access networking protocol, a learning object to study and analyse the protocol operation and mechanism is designed and implemented using sheetlets. The model integrates several spreadsheet and graphical objects, and tools. It also incorporates the Active-X controls that are programmed and set using Visual Basic for Applications (VBA).

In this section, we will illustrate the learning object model designed to implement and simulate CDMA data communication protocol. The model is used to illustrate the concepts of representations, *encoding*, *signalling*, *transmitting*, and *decoding* of data frames among a set of network stations. It is designed using sheetlets that are supported by spreadsheet tools and computer graphics.

The implementation of this model used several spreadsheet and graphical components among the elements listed in Table 1. The model consists of three integrated and linked sheetlets, namely, *encoding*, *signalling*, and *decoding*.

The *encoding* sheetlet is depicted in Figure 3. This sheetlet includes a collection of transmitting stations that can send data frames using CDMA protocol. Each station can send a stream of data bits. A station sends data that can be either bit 0 or bit 1, or it can be in the silent mode, when there is no data to be transmitted. So, to distinguish three cases of data transmission, specifically, 0, 1, or silent, three radio-button controls per each station are used for this purpose. These buttons can allow the user to set the desired state of the station and the data to be transmitted.

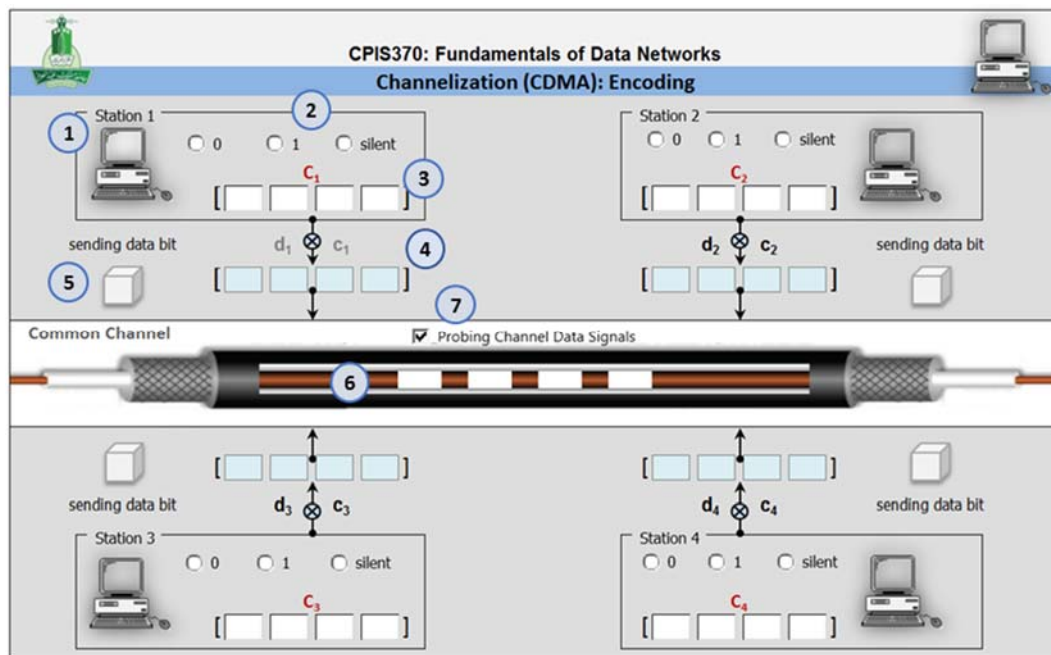


Figure 3: CDMALA sheetlet for data encoding.

The *encoding* sheetlet consists of five parts, four of which are representing the four communicating stations. The fifth part is representing the transmission media, the coaxial cable in this case.

In this sheetlet, each of the four parts includes seven components which are used to input, output, and control the actions to be performed. Table 2 lists those components, their count per one station, description and purpose of their use, and the way of the settings or the source of their data.

Table 2: Components of the encoding sheetlet.

#	Component	Description/Purpose of use	Setting/Source
1	1 station textbox	display sent data	selected radio button
2	3 radio buttons	select data bit to be transmitted	0: -, 1: +1, silent: 0
3	4 input textboxes	enter the station chip code	one row of equation 13
4	4 chip textboxes	display encoded data	using equation 5
5	1 data cube	display transmitted data	selected radio button
6	4 channel textboxes	display channel signals	using equation 6
7	1 checkbox button	probe channel signals	checked: display signals

The user can enter the chipping code sequence per station in the designated textboxes. The inner product of the data transmitted by the chip is displayed to the user as an output. The networking cable is used to visualize the shared link. A checkbox is used to allow the user to probe the signals over the transmission medium.

The *signalling* sheetlet allows the user to visually observe and analyse all the transmissions in terms of digital signals. It graphically displays the signals sent by each transmitting station and the overall signal on the channel. The sheetlet is depicted in Figure 4.

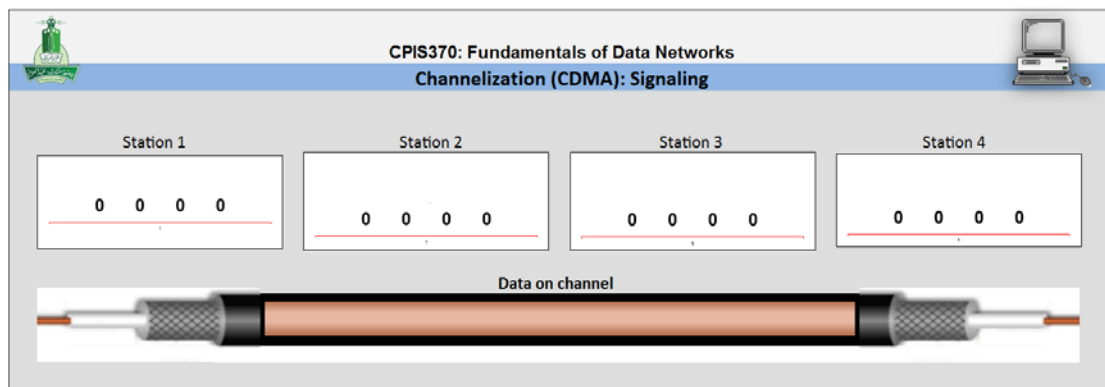


Figure 4: CDMALA sheetlet for data signalling.

Figure 5 demonstrates the sheetlet designed for CDMA data *decoding*. This sheetlet includes sending and receiving parts of the network. It visually performs the decoding operation based on the user selections. Some parts of this sheetlet are linked to the decoding sheetlet.

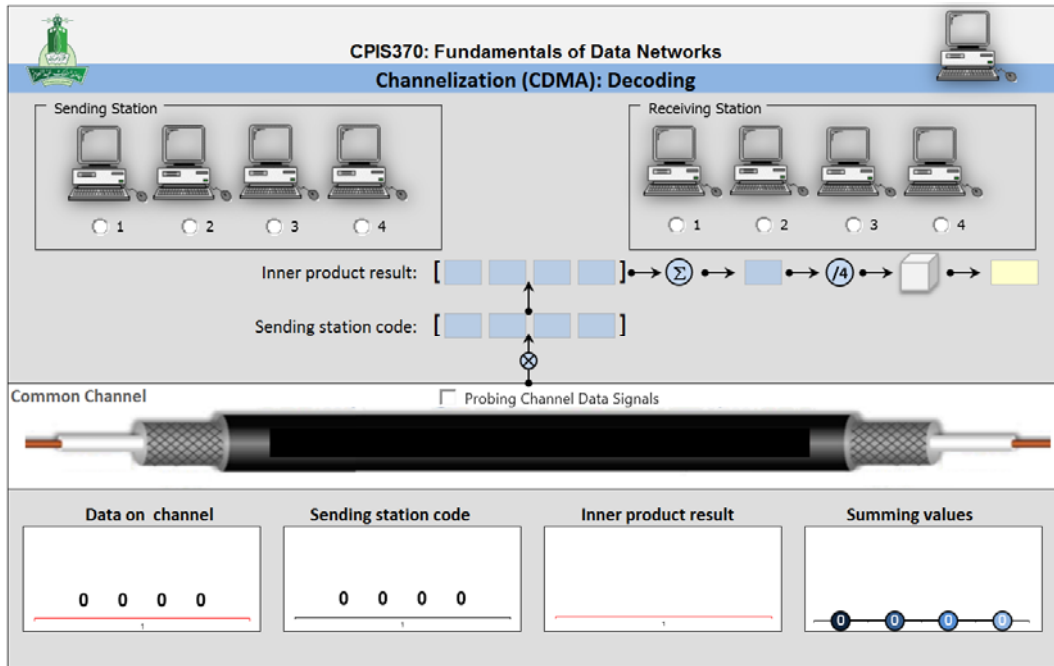


Figure 5: CDMALA sheetlet for data decoding.

9. Experimentation

The sheetlet learning object can be used for experimentation and analysis of the CDMA data communication protocol. The user can set station states and enter the chip codes. Based on the settings used in our design, four chip codes are required. The recursive use of equations (1) and (2) generates chip codes for four stations. This will result in the following chips:

$$W_4 = \begin{bmatrix} +1 & +1 & +1 & +1 \\ +1 & -1 & +1 & -1 \\ +1 & +1 & -1 & -1 \\ +1 & -1 & -1 & +1 \end{bmatrix} \quad (16)$$

Figure 6 shows the CDMA sheetlet learning object in action, selected the data bits to be transmitted by all the stations, and entered the chip codes for all the stations.

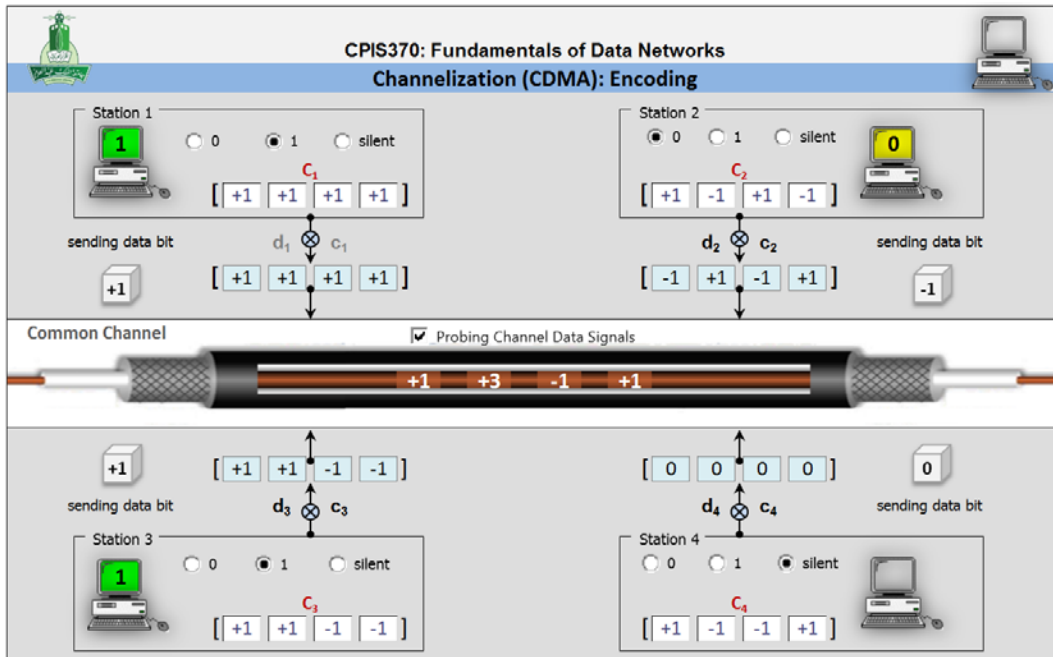


Figure 6: CDMALA sheetlet for encoding stage.

The data signals on the common channel can be probed to examine the data sent by all the participating stations.

The second sheetlet of the learning object displays digital signals sent by all the stations in the transmission domain. Figure 7 depicts these signals.

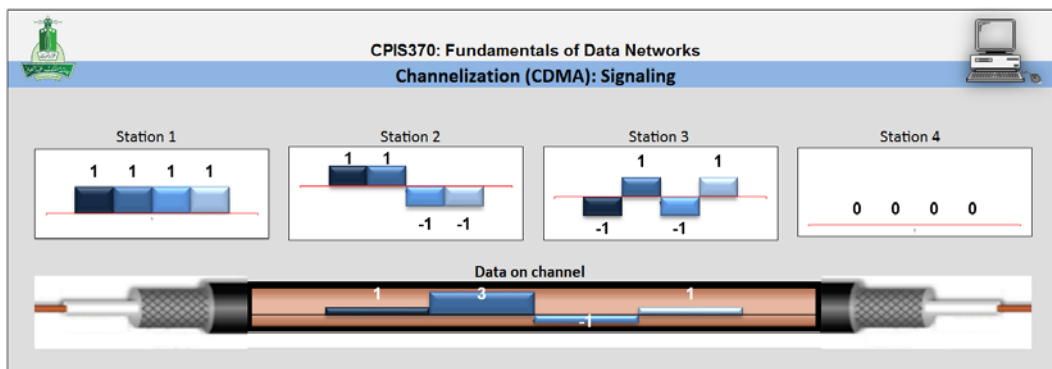


Figure 7: CDMALA sheetlet for signalling.

This sheetlet additionally shows the shared link signals, so the learner can realize the actual mechanic of the communication protocol.

The third sheetlet of the CDMA learning object is the decoding stage sheetlet as depicted in Figure 8.

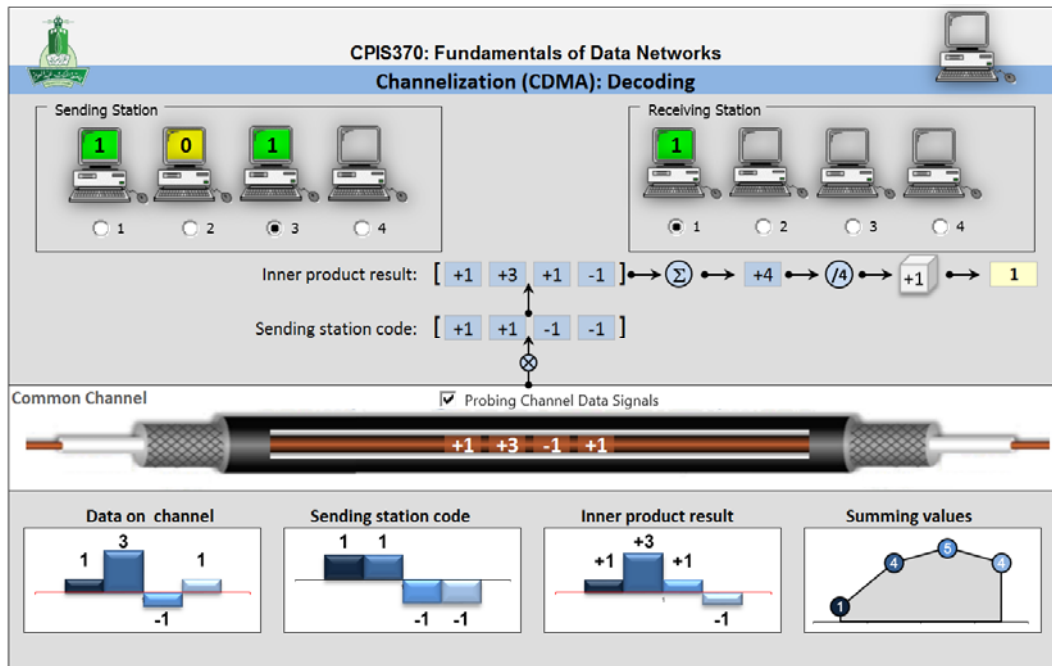


Figure 8: CDMA learning object sheetlet: decoding stage.

This sheetlet allows the user to choose the sending and receiving stations. The sheetlet is linked to the encoding sheetlet, so it inherits data from the transmitted data at the encoding stage. Moreover, it demonstrates the process of data decoding, and finally it displays to the receiver terminal the sent data with coded colour to signal transmission completion. Furthermore, this sheetlet displays to the user four insets which are: data on channel, sending station code, inner product result, and accumulative sum of the inner product. To facilitate user tracking of data transmission, the link cable with the transmitted data are inherited and displayed in this sheetlet.

10. Discussions

The learning, teaching, and analysis of the behavior of CDMA data communication and networking protocol can simply be performed by sheetlet-based learning object demonstrated in this paper.

The learner has the chance to explore the effects and consequences of different scenarios of data transmissions. Moreover, essential concepts of this protocol can be tested, gained and comprehended from this learning object in an easy to handle and use way. The networking concepts such as data representation, chipping codes, orthogonality, inner product, shared transmission link, ... etc., can be easily learned and achieved from the use of this model. As an example, the student has the chance to explore and experiment with the use of different chip codes to observe the effects of using incorrect codes that do not satisfy the selection criteria. This is demonstrated in Figure 9, where a chip code that does not match with the chipping code selection criteria is entered. As can be noticed, the sender station, in this case station 1, is sending data bit of 1, and the receiver station, in this case station 3, is receiving incorrect data transmission, specifically, the station received bit 0.

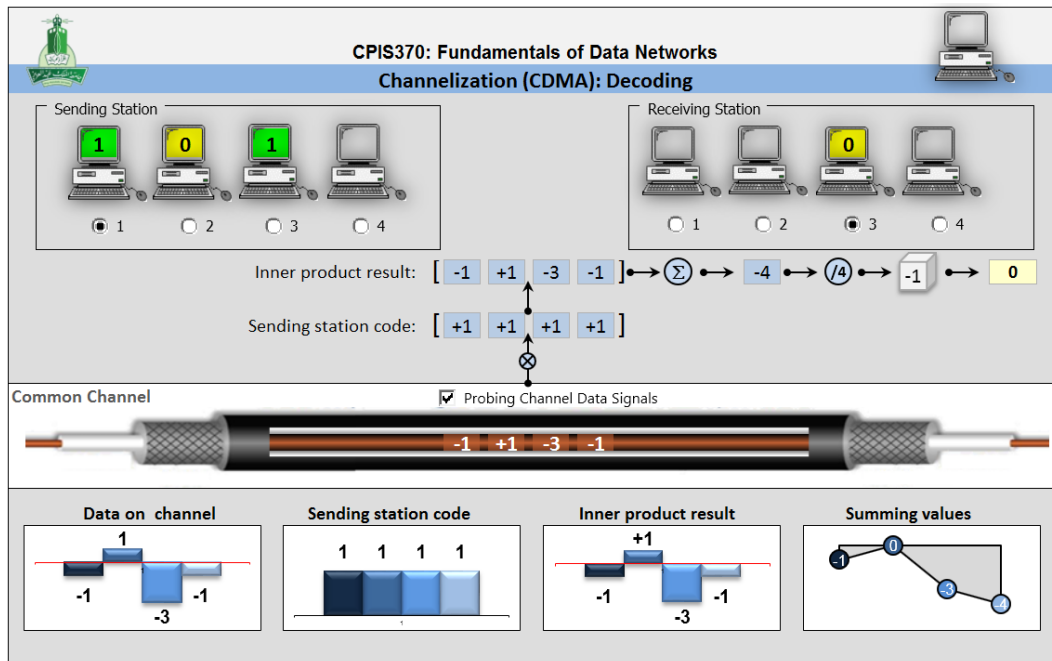


Figure 9: CDMA learning object sheetlet: incorrect data decoding.

The students in computer data communication and networking courses can utilize the learning object to simulate data traffic which is used to explore and analyse a network that uses common access CDMA protocol for data transmissions among its nodes. The analysis can include the changes of the parameters and their consequences on the network behaviour.

Many other experiments can also be performed, and their output results can be observed using this learning object. Students who are using this model can concentrate only on examining the network protocol behaviour rather than being unduly concerned about programming and related debugging and testing issues.

Compared to other CDMA simulators, such as SciLab-based [23], MatLab-based [24], and some other, the CDMALO presented in this paper is distinct in terms of visualization, easiness of use and implementation. The CDMALO can be used for educational purposes as it illustrates visually the mechanism and operation of the protocol. The other CDMA simulators display the analysis of the protocol and the results without showing the details of the protocol functioning and the flow of its operation. In general, CDMALO can be used as a preliminary stage for the other simulators to introduce the basic concepts of the protocol to the students.

11. Outcomes

We have used the developed learning objects of the data communication and networking and shared them among the instructors and the students for several academic years.

The students reported some advantages of using those developed objects in learning the concepts of data communication and networking. The students stated that they found many advantages of using those objects in learning the concepts of data communication. They mentioned that the learning objects assisted them to realize the concepts of computer networking protocols by representing them in an interactive and visualized manner. The learning objects facilitate the concepts and make the connection between the subject components. Some students commented that it is much simpler to visualize the concept, to understand it, and to remember it using the learning objects.

Another advantage of using the learning objects is that students have the chance to use them to work on their own. From our observations of the use of the implemented teaching objects, students showed better and faster understanding and increasingly participation in the topics covered using learning objects. That time was exploited in education by giving them more time that they could spend for extra course activities and discussions. Some instructors expressed their wish to apply the model of presentation-based animations on other topics as well.

From our in-class practice, we found that using the learning objects motivated the students to participate and share their knowledge. Moreover, when we assigned practical computer projects related to the networking protocols, such as CDMA, the number of students submitted and completed their final reports and deliverables was increased compared to previous times when students were asked to build their own projects using high-level programming languages.

Further investigation can be conducted in terms of the effects of using sheetlet-based learning objects on the students learning. This can be performed by collecting and analyzing statistical surveys.

12. Conclusions

This paper demonstrated the design of a learning object for simulating CDMA data transmission protocol that is taught to data communication and networking college level students. The implementation model is based on the use of sheetlets. The model is an efficient alternative to the command line interface models which lack the visualization and interactivity features with the topic matter, or to the resources consuming sophisticated software packages. Moreover, the designing method can free the designers from many tasks of other implementation techniques, such as designing and writing programs using high-level programming languages. The approach discussed in this paper is efficient resources utilization compared with other technology-based implementation alternatives

The students can use the proposed models on their own and in e-learning settings. They can use them for exploring and drilling, extermination, and as hands-on experience for the various topics. The students who are given related tasks to study and investigate showed better responses to the analysis of the computer networking protocols using ready-made models rather than using their own implementations. That was observed by the fewer number of submissions and completions of the assigned tasks and projects by students who submitted their final reports using their

own models compared to almost full number of submissions and completion when the students are given the learning object models.

The technique for implementing the models discussed here could be extended to other data communication and networking protocols, as well as, to other disciplines of science and technology.

Some limitations of sheetlet-based learning objects were encountered during the implementation of the models. These limitations include limited interactivity and animations, which can be overcome by some other tactical alternatives, such as displaying or hiding text or toggling colours. Another drawback is faced with the design of the models, that is due to the limited flexibility when integrating graphics within a computational sheetlet.

For future work, other computer network protocols will be implemented and investigated to develop more general platform for the design of sheetlet-based learning objects. Furthermore, spreadsheet sophisticated features, such as exploiting other forms of control in the design and utilizing advanced VBA capabilities will also be incorporated for more flexibility and easiness of using the final developed educational sheetlet-based learning objects.

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