Biologia Futura: treatment of wastewater and water using tannin-based coagulants

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Abstract

Industrialization and urbanization are mainly responsible for environmental pollution generating enormous amount of wastewater which needs to be treated. Wastewaters from various sources are toxic to humans and livestock, as well as posing environmental risks. Various treatment approaches have been used for the elimination of contaminants from water and wastewater. Coagulation/flocculation processes are the most commonly used techniques in water treatment for improving the condition of turbid water and removing suspended particles by destabilization and the creation of larger, heavier flocs that aid in sedimentation. Flocculants, both organic and inorganic, have long been used in wastewater treatment. The use of natural coagulants/flocculants for water and wastewater treatment has become essential due to the health risks associated with chemical flocculants. Tannin, a natural coagulant, has been suggested as substitute of chemical coagulants. Tannins are present in the leaves, fruits, barks, roots, and wood of trees as a secondary

metabolite. Tannin-based coagulants derived from a variety of plant sources have been successfully used in the treatment of water and wastewater. This review summarises the current status and strategies on applications of tannin-based coagulants exploiting the eco-friendly green materials in water and wastewater remediation for the sake of pollution free environment.

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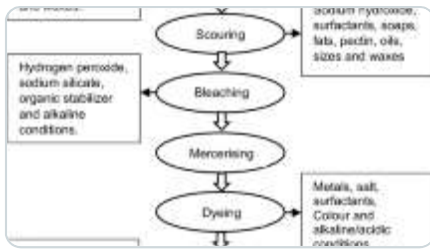
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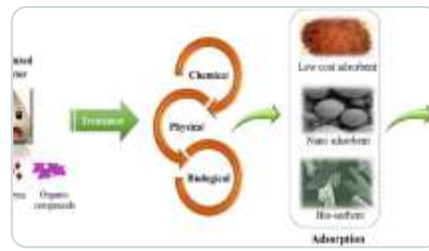
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Introduction

Concerns about the use of water supplies, their availability, and reutilization have grown in recent years. Water shortage is a common occurrence, as wastewater is discharged to the atmosphere without adequate effluent treatment to eliminate contaminants prior to release to the environment. In India, sewage water generation from classes I and II is projected to be 38,255 MLD, with only 11,787 MLD being handled. Untreated wastewater contaminates groundwater, rivers, and other bodies of water, rendering them unfit for human use (Singh et al. 2016). As a result, it is critical to concentrate on the advancement of cost-effective emerging technologies aimed at ensuring the availability of water resources to the global population (Machado et al. 2020).

Since coagulation/flocculation techniques are simple and cost efficient, they are the most commonly used treatment in water and wastewater treatment to remove various dissolved contaminants, suspended solid (SS) particles, and emulsified oil from wastewater (Ortiz-Oliveros and Flores-Espinosa 2019). Coagulation is the accumulation of destabilized particles into larger flocks that can

be easily separated using basic techniques including sedimentation and filtration (Hameed et al. 2016). Various materials have been used in the coagulation and flocculation processes, including (1) organic flocculants such as cationic (such as epichlorohydrin/dimethylamine polymers) and anionic polyelectrolytes (such as polyacrylamide), amphoteric and hydrophobically modified polymers, and naturally produced flocculants (2) inorganic and organic coagulants such as polyelectrolytes (coagulant aids) and metal slats (e.g., aluminium sulphate). Inorganic and organic polymer flocculants are the most commonly used materials in wastewater treatment. Inorganic flocculants are mostly made up of aluminium and iron, and they have a strong treatment effect on suspended solids and colloidal particles, but they have some disadvantages. Sludge produced during wastewater treatment with an aluminium salt flocculant is often used as fertilizer in agriculture. However, high levels of aluminium in the soil pollute the environment and damage plants (Tietz et al. 2019). Furthermore, free aluminium ions pollute water by infiltrating lakes, rivers, and groundwater by infiltration, diffusion, deposition, and migration, resulting in water contamination and health risks. According to one study, traces of aluminium contained in food caused acute carcinogenic and genotoxic diseases (Tietz et al. 2019). Moreover, Zhang et al. (2015) reported that Alzheimer's disease could be caused due to the remaining traces of Aluminium (Al) in the treated wastewater or marine ecosystems. The use of iron flocculant is also discouraged due to its corrosive nature. It has the potential to speed up the aging of equipment and boost the cost of water treatment (Porwal et al. 2015). Polyacrylamide or acrylamide sodium acrylate is the most commonly used flocculant for water treatment because of benefits such as quick flocculation, low dosage, and easy separation. But this flocculant causes adverse health effects due to the existence of trace acrylamide monomers, which are potentially toxic and carcinogenic (Im et al. 2019; Liu et al. 2019). Chemical coagulants, such as aluminium polychloride, aluminium sulphate, and ferric chloride, are the most commonly used coagulants nowadays, and they can cause environmental issues by producing large volumes of non-degradable sludge, resulting in high costs to treat and dispose of the sludge, as well as posing a risk to human health (Hameed et al. 2016).

Many studies have been focused on producing eco-friendly coagulants and flocculants from natural sources to replace traditional ones due to the disadvantages of traditional ones. Coagulants and flocculants made from natural resources are generally healthy, non-toxic, and contain a limited amount of sludge, which has a higher nutritional value for microorganisms, making sludge biodegradation simpler. Furthermore, when using natural coagulants/flocculants, no pH adjustment is needed, and these products are non-corrosive with low maintenance costs (Choy et al. 2014; Lapointe and Barbeau 2020). Fruit and agricultural residues, starch derivatives, gums alginate, and tannins are examples of natural coagulants/flocculants (Oladoja 2015; Salehizadeh et al. 2018a, b). Tannins have the potential to be a source of coagulant and flocculant agents. Tannin, a naturally occurring water-soluble polyphenol found in most plant cells, has long been used as a plant-based coagulant. Turbidity, colourants, suspended particles, chemical oxygen demand, algae, and heavy metals have all been successfully removed using a tannin-based coagulant in water and wastewater

treatment around the world (Ibrahim et al. 2021). Tannins are plant-derived compounds that could be used as a replacement for chemical coagulants/flocculants, which cause environmental and economic concerns by producing large amounts of non-biodegradable sludge, expensive treatment and disposal costs, and a risk to human health (Hameed et al. 2016; Roselet et al. 2016; Salehizadeh et al. 2018a, b; El-Gaayda et al. 2021). Among the many applications for tannins, the synthesis of coagulant agents is one of the most intriguing. A factorial design is used to evaluate the possible combinations of two types of tannin extracts (*Acacia mearnsii* and *Schinopsis balansae*) under three commercially available products (Clarotan, Weibull Black, and Quebracho colorado) and three types of amine compounds in the synthesis of tannin-derived coagulants (ammonium chloride, glycidyltrimethylammonium chloride and diethanolamine). The best product was discovered to be one made from Clarotan and diethanolamine, which was very effective when tested with surface river water, dye, or surfactant-polluted wastewater after many repeatability checks (Beltran-Heredia et al. 2010). This article reviews the history and current status of tannin-based coagulants/flocculants, including their sources and characteristics, chemical modification process involved in cationization of tannin, the flocculation mechanism of tannin-based coagulant, with the goal of shedding light on their potential applications in water and wastewater treatment.

Sources of tannins

Tannins are defined as the most common water-soluble polyphenolic secondary metabolites with high molecular weight ranging from 500 to more than 3000 Da that are present in bark, stems, seeds, roots, buds, and leaves, accounting for 5 to 10% of dry vascular plant materials (Barbehenn and Constabel 2011; Tomak and Gonultas 2018; Giovando et al. 2019; Das et al. 2020). Tannins can also be found in fruits and vegetables, for example: grapes, blackberries, strawberries, walnuts, cashew nuts, hazelnuts, mangoes, tea (Clifford and Scalbert 2000; Das et al. 2020), wine (Corder et al. 2006) and pomegranate (Scalbert et al. 2002). Also, birds-foot trefoil (*Lotus corniculatus*), sainfoin (*Onobrychis viciifolia*), sulla (*Hedysarum coronarium*) and lotus (*Lotus pedunculatus*) (Waghorn 2008).

Quebracho is the common name for the South American trees, like *Schinopsis balansae.* Because of its high percentage tannin content and relatively simple reproduction process, it was considered as the first source of tannins before *Acacia mearnsii*. Quebracho, on the other hand, is still an essential tannin feedstock (Pizzi 2008), and its quality in condensed tannins has been extensively determined in unique studies (Streit and Fengel 1994; Vivas et al. 2004). Also, previous researchers observed that high levels of condensed tannin can be found in the wood of quebracho (*Schinopsis balansae*) and chestnut (*Castanea sativa*), in the sheets of gambier, or in the bark of pine (*Pinus radiata* and *Pinus nigra*), black mimosa (*Acacia mearnsii*) or oak (*Quercus* spp.) (Pizzi 2008; Arbenz and Averous 2015).

The structure of condensed tannins is given a cationic character by this chemical modification process in an acidic medium (Beltran-Heredia et al. 2012). Furthermore, these modified structures take an amphoteric character, making it easier to remove ionised heavy metals and lower various physico-chemical parameters (Heredia and Martín 2009a, b). Tannins are a type of secondary metabolite made up of a heterogenous group of water-soluble polyphenolic compounds (dos Santos et al. 2017; Pizzi 2019).

The basic tannin structure in aqueous solution, as well as potential molecular interactions, is shown in Fig. 1. The efficacy of tannins is largely determined by the chemical structure of tannins extracted from plants and the degree of tannin alteration, according to numerous studies (Ozacar 1997; Sanchez-Martin et al. 2010a, b). Tannin has no metals in its composition and does not absorb the medium's alkalinity because it does not undergo hydrolysis in solution, so its coagulant efficacy is still optimal. The tannin structure also varies depending on the location and origin of the plant (Ibrahim et al. 2021).

Fig. 1
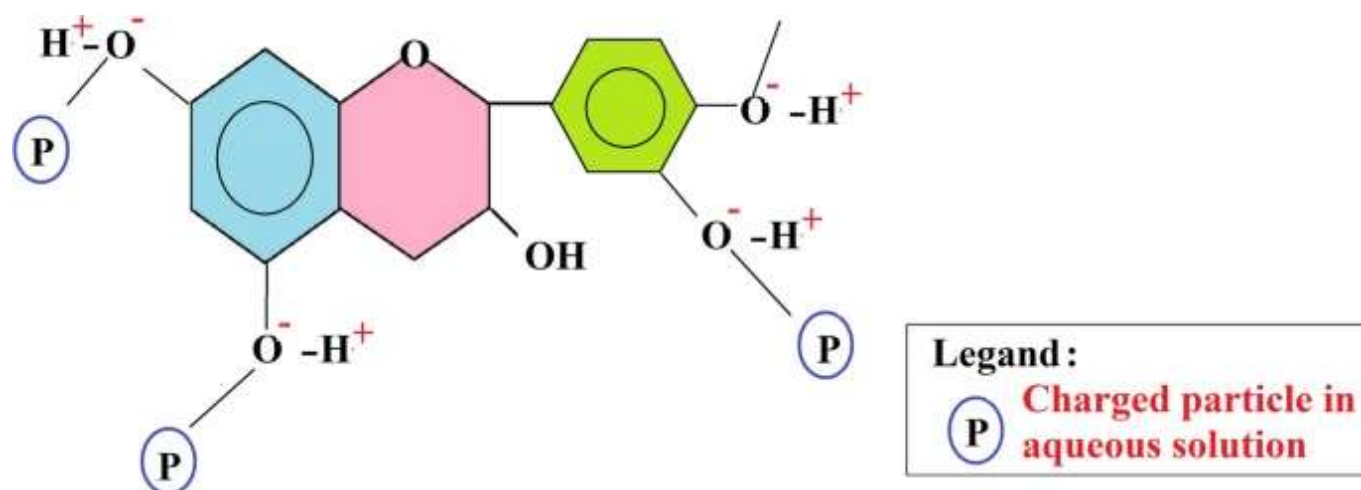
Representation of basic tannin structure

The word "tannins" refers to a wide range of chemical compounds. They have traditionally been used for tanning animal skins, hence their name, but some of them are now used as coagulants. Their natural origin is as secondary metabolites found in the bark, fruits, leaves and seeds of plants (Schofield et al. 2001; Kim et al. 2021). Thakur and Choubey (2014) reported that, tannin-based coagulant are efficient in wastewater management. Although the bark of *Schinopsis* and *Acacia*, trees is the most common source of tannins for the leather industry, other non-tropical trees such as *Pinus, Castanea* and *Quercus* are also noted to be tannin-rich. *Querbacho* tannin extract is believed to be primarily made up of the building blocks viz. resorcinol, catechol, and pyrogallol (Pasch et al.

2001). This complex chemical structure can be used to include many active groups that could improve the agent's coagulant function (Pizzi 1994). Traditional tannin sources include *Schinopsis balansae* (Quebracho), *Castanea sativa* (Chestnut), and *Acacia mearnsii* (Black Wattle). Tannins defend trees from fungus, diseases, insects, and herbivorous animals by acting as plant defensive agents (Sharma 2019; Das et al. 2020).

Tannin based coagulants

Tannin-based coagulants have been used in water and wastewater treatment for coagulation and flocculation. There are scientific sources on the capacity of tannins to treat water. Tannins obtained from *Valonia*, an autochthonous tree from Turkey, were characterized and used for wastewater coagulation treatment by Ozakar and Sengil (2000). Tannin based gel was used for the removal of lead from water. Process of metal removal was improved by tannin gelification (Zhan and Zhao 2003). Moreover, Palma et al. (2003) used tannin extracted in situ from *Pinus radiata* bark in order to polymerize a solid which was used for heavy metal removal. Bark was combined with tannin solid into adsorption column. They are polycyclic aromatic compounds and can be used as a substitute for chemical coagulants/flocculants. There are three types of tannins in terms of chemistry: hydrolysable, condensed, and mixed tannins (Beltrán-Heredia et al. 2011a, b, c). And also, they are classified as ellagitannins, and gallotannins based on their structure (Khanbabaee and van Ree 2001). Inorganic salts can be used as polymeric additives, or the Mannich reaction can be used to reinforce cationic regions for direct flocculation (Beltran-Heredia et al. 2010). A compound with a primary or secondary amine, formaldehyde, and an active hydrogen atom (substrate) are needed for this condensation reaction. These compounds induce aminomethylation of the substrate and the formation of a Mannich base (Tramontini and Angiolini 1994; Subramaniapillai 2013).

Tannin inhibits the growth of a broad range of microorganisms. Inhibition of microbial enzymes, deprivation of substrates and metal ions needed for development, and direct impact on bacterial membranes have all been proposed as inhibitory mechanisms. However, high concentrations of tannin compounds (100 mg L^{-1}) are needed to display a significant inhibition of microbial development (Gross et al. 2012).

By using tannin-based coagulant, it was possible to show that *Opuntia* sp. could reduce the turbidity by 98% (Sanchez-Martin et al. 2010a, b). Tannin was reported as a new and feasible source of treatment agents by Beltran-Heredia et al. (2011a). They investigated the ability of these new products in several fields such as removal of turbidity, surfactants, removal of heavy metals etc. Couto et al. (2013) reported the optimization time of coagulation, flocculation and sedimentation of the chemical coagulant by aluminium sulphate as a coagulant and tannin as coagulant aid. Removal efficiency of colour, turbidity, chemical oxygen demand (COD), biochemical oxygen demand (BOD) and total solids were evaluated. Apart from this some more tannin-based coagulants/gel are

reported by several researchers viz. Black wattle tannin-gel for removal of Cr (VI) (Rodrigues et al. 2015), Valonia tannin resin for removal of Pb II and Cu II (Sengil and Ozacar 2009), Mimosa tannin gel for removal of Cu II (Sengil and Ozacar 2008) and *Pinus* tannin gel for removal of Zn II and methylene blue (Sanchez-Martin et al. 2011).

Tanfloc—a commercial coagulant

The name TANFLOC, which is a trademark owned by TANAC (Brazil), has been proposed for a commercial coagulant and flocculant. It is a tannin-based product with a high flocculant power that has been changed by a physicochemical process. It is made from the bark of the *Acacia mearnsii* tree. This tree is extremely popular in Brazil and contains a high amount of tannins. TANFLOC is a vegetal water extract tannin primarily composed of flavonoid structures with an average molecular weight of 1.7 kDa, according to TANAC specifications. The TANFLOC structure includes additional groups such as hydrocolloid gums and other soluble salts. The cationic character of TANFLOC is due to a chemical modification that contains quaternary nitrogen (Singh et al. 2016).

There is some more tannin-based commercial coagulant reported by Beltran-Heredia et al. (2012) viz. TANFLOC, Acquapol C1 and Silvafloc. ACQUACHIMICA, S.A. manufactures a Acquapol C1 (Brazil). Furthermore, SILVATEAM, S.A. (Italy) supplied Silvafloc. *Acacia mearnsii* was used for TANFLOC and Acquapol C1 as a source of tannin, while Quebracho was the tannin source for Silvafloc.

Modification of tannin

The efficacy of tannins mainly depends on the chemical structure of tannins and the degree of tannin modification (Sanchez-Martin et al. 2010a, b; Ozacar 1997). Several references have been reported regarding the chemical modifications. Most of them include the patents including the specific process for TANFLOC which is mentioned. The scientific literature refers a reaction mechanism that involves three reagents such as tannin mixture, mainly polyphenol tannins whose structure may be same as flavonoid structures such as resorcinol A and pyrogallol B rings; an aldehyde such as formaldehyde and an amino compound, such as ammonia or a primary or secondary amine compound (Schofield et al. 2001). The three reagents under certain conditions of pH (7) and temperature (80º C) may produce the flocculating agents. An interesting study was conducted in application of commercial tannin containing both amine and phenolic groups for water treatment which suggested that tannin is cationic in nature since there is a single tertiary amino group per monomer unit. The tannin also shows amphoteric nature as a result of the presence of phenolic groups (Vijayaraghavan et al. 2011). A cationization reaction is needed to modify the structure of tannins before they can be used in the direct flocculation process. The main goal is to give the molecules a cationic character, which favours negative colloids charge neutralization during the flocculation process. The Mannich reaction is a cationization process used in tannins that

involves the addition of a nitrogen compound to formaldehyde, resulting in the formation of a high molecular weight tannin polymer with an amphoteric character (Sanchez–Martin et al. 2014; Hameed et al. 2016). Modification of *Acacia* Tannin (MAT) was reported by Lugo et al (2020). The modification of tannin was conducted by the Mannich reaction using ammonium chloride and formaldehyde under laboratory condition as shown in Fig. 2. The coagulation-flocculation process with the modified *Acacia* tannin (MAT) was found to be very effective both for the removal of turbidity and heavy metals and also for the removal of organic material and total suspended solids.

Fig. 2
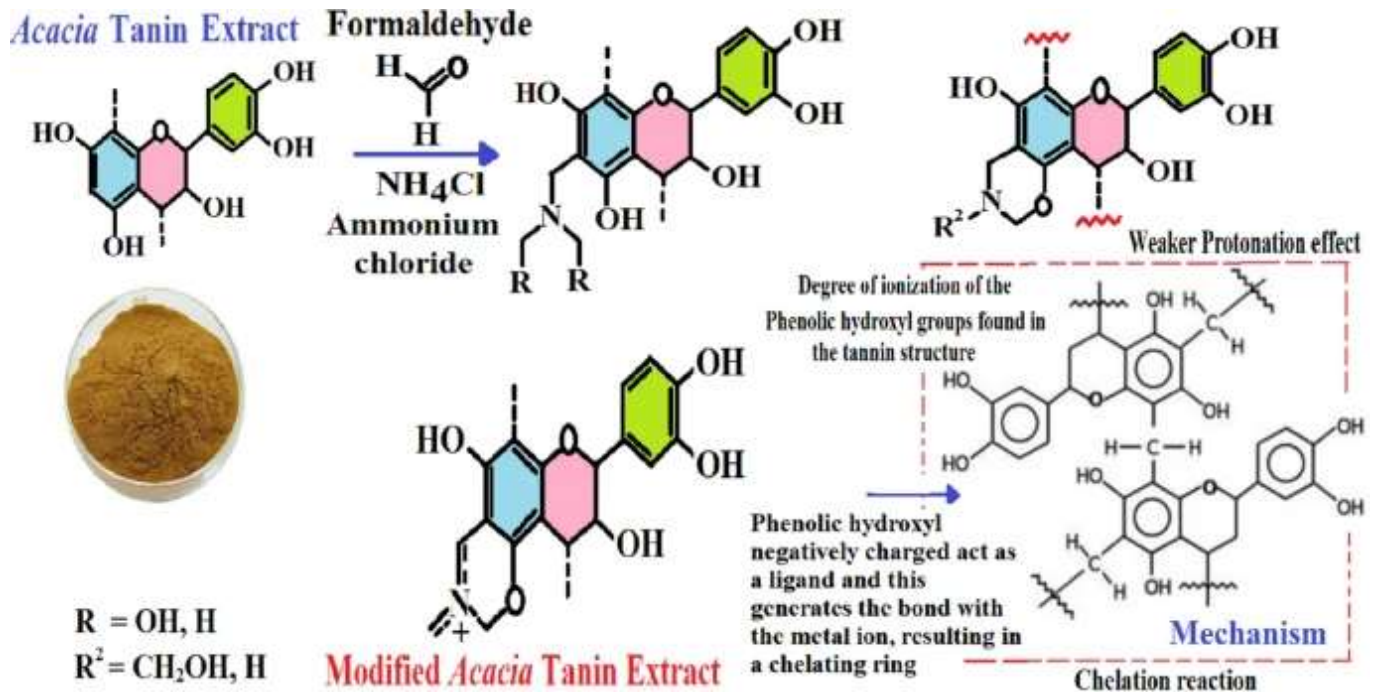
Modification of *Acacia* tannin (AT) extract into modified *Acacia* tannin (MAT) by Mannich reaction using ammonium chloride and formaldehyde

A chemical modification on *Persimmon* tannin (PT) extract by immobilizing bisthiourea (BTU) ligand was reported by Gurung et al. (2012) for the recovery of precious metals. The chemical modification of gelatin Persimmon tannin (PT) powder with BTU functional group was done by chloromethylation.

Mechanism of coagulation/flocculation

The flocculation mechanism associated with tannin-based flocculant depends on coagulation/flocculation parameters such as flocculant dosage and pH of effluent, as well as the type of wastewater being treated and the source of the tannin (Ibrahim et al. 2021). Charge neutralization, electrostatic patching and polymer bridging are the common flocculation mechanism. The most widely accepted mechanism for plant-based bio-flocculation is polymer

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bridging (Das et al. [2021]). The majority of wastewater contamination is caused by colloids and suspended particles with a negative surface charge, which creates electrostatic repulsion among themselves, prohibiting sedimentation and extraction. When a cationic material, such as a natural flocculant derived from modified tannins, is introduced, these particles become destabilized (Beltran-Heredia et al. [2012]). Yang et al. ([2019]) studied the flocculation mechanism at different pH and optimal dosage of TANFLOC. Charge neutralization mechanism was the main mechanism at pH 4.5. While at pH 8.0 due to loss of the net charge, zeta potential became opposite with an overdose of TANFLOC. In this case, electrostatic patching was the main mechanism of flocculation. Furthermore, at pH 10.5, due to increase in negative charges TANFLOC molecules will be unstable and caused greater electrostatic repulsion which affects the flocculation performance. At higher pH zeta potential will be far from zero still TANFLOC showed some removal ability, this was explained by the bridging mechanism. Furthermore, the researchers have shown that the modified tannins have flocculation and removal properties (Heredia and Martín [2009a], [b]; Hameed et al. [2018]). There have been reports on the different forms of wastewater treated with tannin-derived coagulants.

Wastewater treatment

Municipal wastewater

Hameed et al. ([2020]) recently published a study that looked at the effects of TANFLOC, a natural tannin-based coagulant and flocculant, as a pre-treatment agent for a biofilm system used to treat municipal wastewater. The effect of using TANFLOC for a longer period of time (around 2 months) on the biofilm bacterial population was investigated. TANFLOC had an impact on the characteristics of wastewater, according to the findings. The bacterial population of the biofilm was responsible for the improvement in the nitrification process. TANFLOC use resulted in a substantial increase in the percentage of ammonia oxidizing bacteria (3.33%) and nitrite oxidizing bacteria (7.8%) in the TANFLOC-treated experiment, compared to just 0.073% and 0.19% in the without TANFLOC-treated experiment.

TANFLOC also has shown around 50% removal of BOD and COD and almost 100% turbidity removal from municipal wastewater. The coagulation process was not affected by temperature (Beltran-Heredia et al. [2009]). Tannin, a naturally occurring water-soluble polyphenol found in most plant cells, has long been used as a plant-based coagulant. Turbidity, colorants, suspended particles, chemical oxygen demand, algae, and heavy metals have all been successfully removed using a tannin-based coagulant in water and wastewater treatment around the world. The chemical structure of tannins and the degree of tannin alteration, both of which are linked to the plant source from which they are taken, determine their coagulant potency (Ibrahim et al. [2021]).

Industrial wastewater

Lugo et al. (2020) studied the Mannich reaction-modified tannin for industrial wastewater treatment. Using modified *Acacia* tannin (MAT) as a coagulating agent, the removal of heavy metals such as chromium, mercury, and copper from industrial wastewater was tested. Instrumental analysis such as atomic absorption spectroscopy (AAS), nuclear magnetic resonance (NMR), Fourier transform infra-red spectroscopy (FTIR), and direct mercury analyser were used to test the active tannin modification (DMA). Water content, chemical oxygen demand (COD), turbidity, and total suspended solids (TSS) were all evaluated as well. Copper (60%), mercury (50–80%), and chromium (67%) had the largest percentage of removal, followed by COD (88%), TSS (86%), and turbidity (94%) with a dose of 375 ppm of MAT at pH 10. The modified *Acacia* tannin was found to be effective in removing traditional parameters as well as heavy metals in substantial amounts.

According to the findings of Aboulhassan et al. (2016), a tannin-based coagulant was more efficient than $FeCl_3$ and $Al_2(SO_4)_3$ in treating COD and colour in paint manufacturing effluent. When compared to metal salts coagulant, no pH adjustment was required, and coagulation utilising the tannin-based coagulant removed more than 87% COD and 99% colour while generating a lesser volume of decanted sludge.

Grenda et al. (2020) performed upscaling of tannin-based coagulants for industrial wastewater treatment. Tannins were extracted from the bark of *Acacia mearnsii* and the wood of *Schinopsis balansae*, also known as Quebracho. Mannich aminomethylation with formaldehyde and dimethiamine hydrochloride was used to modify the tannins on a laboratory scale. The formaldehyde dosage and reaction time were varied while the Mannich solution activation time was kept constant, and the effects on the viscosity of the generated bioflocculants were assessed. The Mannich reaction for tannin was upscaled, and the process was produced at a one-litre scale. After that, industrial wastewater was tested with modified South African tannin and modified Quebracho tannin. With the simultaneous addition of a cationic, 40% charged polyacrylamide, good turbidity (93%) and decolorization (89%) were achieved with a low dose (5 ppm) of the latter additive. On a pilot scale, a tannin-based coagulant from *Acacia mearnsii* was successfully used to treat industrial wastewater. It was demonstrated that it treated the water satisfactorily and less sludge was generated.

The production of pollutant-free coagulants and flocculants to replace traditional ones has received a lot of attention. One option is to use tannin-based flocculants, which are found in many plants and are relatively easy to extract. Moreover, in an attempt to use tannins as flocculants, they must be cataionized first that is typically achieved via the Mannich reaction, which necessitates the addition of formaldehyde, a toxic compound. Machado et al. (2020) used chemically modified tannins from *Acacia mearnsii* synthesized via a green method to produce formaldehyde free flocculant and optimized the design using a Central Composite Rotatable Design (CCRD) to fill a void in the

literature. The flocculant synthesis methodology produced excellent turbidity and color removal performance showing turbidity removal (100%) and color removal (89.9%) obtained by using innovative tannin-based flocculant synthesis methodology. Once it is environmentally sustainable, it has the potential to replace traditional coagulants/flocculants.

Landfill leachate

Landfill leachate that has leached as a consequence of natural decomposition of organic material may contaminate groundwater, if not properly treated (Azreen and Zahrim 2018). Banch et al. (2019) used a tannin based natural coagulant to treat stabilized landfill leachate. Tannin that had been modified with an amino group was included in the treatment. The effect of tannin dosage and pH on four responses of selected parameters, namely TSS, COD, NH_3-N, and color were investigated and optimized using Central Composite Design (CCD). A tannin dosage of 0.73 g at a pH of 6 provided the best removal efficiency for TSS, COD, NH_3-N, and color. COD, TSS, NH_3-N, and color removal efficiencies were 53.5%, 60.26%, and 91.39%, respectively. The heavy metals viz. Pb, Fe, Zn, Cr, As, Cu, cobalt, and Cd were all found to be significantly removed from the leachate. The findings showed that using a tannin-based coagulant to remove organic compounds and heavy metals from landfill leachate was successful.

Organic compounds cause the dark color of landfill leachate, which is a critical concern in many countries. As a result, color removal is critical in environmental remediation. Ibrahim and Yaser (2019) confirmed the color removal from biologically treated landfill leachate using a tannin-based coagulant. A tannin-based coagulant was used, along with anionic and cationic polyacrylamide (PAM) as a flocculant. At a pH of 5, flocculation time of 3 min, and a sedimentation time of 10 min, an experiment with a coagulant dosage of 100 mg L^{-1} and 1 mg L^{-1} anionic PAM (APAM) resulted in the highest color removal (81.8%). The use of a tannin-based coagulant and APAM as a flocculant in a coagulation flocculation device showed promising results in the decolorization of biologically treated landfill leachate. Tannin used for this report is a commercial coagulant called Organo-floc, which would be a cationic vegetable-based organic polymer with a low molecular weight that can serve as a coagulant and flocculant. Aziz et al. (2007) discovered a correlation between color removal and chemical oxygen demand (COD), turbidity, and suspended solids removal, indicating that organic matter was the primary source of color in landfill leachate. The coagulation − flocculation method is effective at removing high concentrations of organic matter (Wang et al. 2002), with iron salts and aluminium coagulants being commonly used to remove humic substances from water (Amokrane et al. 1997).

Brewery wastewater

The brewing industry is a significant part of the global economy. Its manufacturing phase produces a lot of wastewaters. Junior et al. (2019) issued a report on using vegetable tannin as a flocculant

agent (TANFLOC SL) for the treatment of brewery wastewater that also includes microalgae from a local brewery's aerated pond. The optimum levels of pH and tannin concentration for turbidity and apparent color removal from wastewater were determined using a sequential 2^2 factorial design and a two factor Doehlert design. Using 0.23 mL L^{-1} of vegetable tannin at pH 4.9 resulted in 99 percent elimination of turbidity and color, resulting in higher efficiency in biomass separation. The elimination of biomass and nutrient components was also assessed: $N-NO_3$ (56.9%), $N-NO_2$ (83.6%), $N-NH_4$ (80.8%), orthophosphate (76.2%), total Phosphorus (82.3%), BOD (69.4%), total Solids (40.8%), and COD (96.5%).

Washing machine wastewater, river wastewater and simulated wastewater

Bioflocculants using modified tannins were reported for the treatment of three types of wastewaters viz. washing machine wastewater, river wastewater and simulated wastewater (Arismendi et al. 2018). A substrate (tannin extract of *Acacia*, Quebracho, and *Castanea*), an amine derivative (ethanolamine, diethanolamine, ammonium chloride), and formaldehyde were used as reagents. In two experimental steps, nine natural flocculants were generated by combining extracts and amines, and these products were tested in three separate wastewater samples. Five physicochemical parameters were examined in phase I. In phase II, 14 biological and physicochemical parameters were evaluated for the three bioflocculants with statistically significant responses and their mixtures. There was a substantial reduction in physicochemical parameters. The bioflocculants acacia–ammonium chloride and Quebracho diethanolamine were the most effective at removing total solids (12–99%), color (93–100%), and turbidity (34–99%). Furthermore, as opposed to aluminium sulphate, natural flocculants had a low mutagenicity index. Furthermore, Sanchez-Martin et al. (2010a, b) investigated the Silvafloc for river water purification and found that a 20 mg/L dose of the coagulant removed 90% of turbidity at neutral pH.

Domestic wastewater

For the pre-treatment of domestic wastewater, a tannin-based natural flocculant (TANFLOC) was combined with ferric chloride. TANFLOC's efficiency for removing BOD (60%), COD (69%), and turbidity (95%) improved by using coagulants including ferric chloride. The optimum value for treating domestic wastewater was 10 parts per million ferric chloride and 15 parts per million TANFLOC (Singh et al. 2016).

Textile wastewater

Two harmful dye contaminants, Palatine Quick Black WAN and Alizarin Violet 3R, have been removed using a new coagulant produced by polymerizing *Acacia mearnsii* tannin extract. The coagulant was made in the lab by etherifying tannins with formaldehyde, and

glycidyltrimethylammonium chloride and its efficiency in dye removal was observed to be high. Low coagulant dosages (around 50 mg L^{-1}) achieved high -capacity levels (around 1.6 for Palatine Fast Black WAN and 0.8 for Alizarin Violet 3R mg dye mg^{-1} of coagulant). The variables were unaffected by factors such as temperature and pH (Beltran–Heredia et al. 2011a, b, c).

Coagulation/flocculation (CF) decontamination of dye-polluted wastewater (DPW) was performed using novel *Luffa cylindrica* seed (LCS) extracts derived through various processing processes. Cibacron blue dye 3GA (a reactive, azo dye) and distilled water were used to recreate the DPW in the lab. The proximal and instrumental characterisation of bio-coagulants was carried out. To predict color/total suspended particle (CTSP) and chemical oxygen demand (COD) clearance rate using bio-coagulants, two models were proposed: Response Surface Methodology (RSM) and Artificial Neural Network (ANN). The input variables include bio-coagulant dosage, wastewater pH, and stirring time. RSM and ANN models have been created based on experimental designs. To examine the appropriateness and predictive ability of both models, regression coefficient (R^2) and mean square error (MSE) were applied and correlated. The collected findings demonstrated that the ANN model was the best predictor of CSTP and COD removal from DPW (Onukwuli et al. 2021).

In another study, a tannin-based coagulant derived from *A. mearnsii* was used in a dual system with cationic PAM flocculant for cosmetic and coloured microbeads industrial effluent treatment. With a simultaneous minimum dosage (5 ppm) of a cationic, 40% charged PAM, 93% turbidity removal and 89% decolorization were obtained. (Grenda et al. 2020).

Urban wastewater

Beltran–Heredia et al. (2010) tested the efficacy of TANFLOC in order to treat urban wastewater. TANFLOC was found to have a high effectiveness in removing turbidity (nearly 100% depending on dosage) and about 50% in removing COD and BOD, making it a suitable coagulating agent with an efficiency comparable to alum. Temperature had no impact on the flocculation and coagulation processes. The optimal agitation speed and time were found to be 40 rpm and 30 min, respectively. The amount of polyphenol in the solution did not significantly increase, and 30% of the anionic surfactants were eliminated. TANFLOC is a flocculant and coagulant that has been shown to be very effective in wastewater treatment.

Grehs et al. (2019) reported that $Al_2(SO_4)_3$ and Tanfloc SG reduced the colour and turbidity of a secondary treated urban wastewater, as well as the bacterial load, immediately after coagulation treatment.

Dairy industry wastewater

To examine the coagulation performance of tannin and polyaluminium chloride (PAC) in dairy sector effluent. The dosage, pH, velocity gradient, and slow-mixing duration for coagulation/flocculation were optimized, and various parameters such as floc aggregation (KA) and breaking (KB) coefficients were computed. A thermogravimetric examination of the produced sludge for both coagulants was also performed. The PAC, in particular, consumed more alkalinity and enhanced the electrical conductivity of the cleared wastewater, whereas tannin performed well across a pH range of 5.0 to 10.0. Furthermore, while PAC usage had the highest KA values, tannin consumption had a stronger resilience to floc breaking during the slow-mixing time. When compared to PAC, the sludge generated from the tannin studies had higher volatile solids, fixed carbon, and lower ash concentration. Tannin, in terms of process performance and wastewater treatment residuals management, is a promising choice for dairy wastewater treatment (Justina et al. 2018).

Water treatment

Tannin-based coagulants have been utilized in coagulation/flocculation process for water purification (Thakur and Choubey 2014). Water can be purified by using water soluble amphoteric tannins, which co-precipitate with suspended impurities in the water. As a result, the treated water contains no residual salts or ions. One of the benefits of using tannin-derived coagulant is that the pH of the suspension is not affected. Furthermore, the formation of flakes is an advantage. Their irregular shape allows for more surface contact, which improves flocculation quality (Kelly et al. 1988; Lamb and Decusati 1999). Researchers discovered that when commercial tannin containing phenolic and amine groups is used for water treatment, it is cationic in nature since each monomer contains a single tertiary amine group. As a result of the inclusion of phenolic groups, this tannin is also amphoteric (Vijayaraghavan et al. 2011).

Algal bloom water contains toxic extracellular organic matter (EOM), which has a negative impact on human health. Yang et al. (2019) investigated TANFLOC's flocculation efficiency on dissolved EOM (dEOM) and bound EOM (bEOM) in EOM care. The removal output of bEOM was better than dEOM. The removal of high molecular weight organic components (>100 kDa) and protein-like substances in bEOM was satisfactory, but removing humic acid, fulvic acid, and soluble microbial product-like substances in dEOM was difficult. TANFLOC was able to effectively remove dEOM and bEOM, owing to its ability to combine with polysaccharide and protein. At pH 4.5, 8.0, and 10.5, respectively, charge neutralization, electrostatic patching, and bridging were the main mechanisms. The study's findings suggested the ways to increase EOM flocculation performance in harmful algal blooms water in order to minimize the environmental risk.

A tannin-based coagulant was used to remove Oocystis algae from freshwater (Barrado-Moreno et al. 2016). Algal removal was tested using Acquapol C1, a tannin-based coagulant agent. This

coagulant is made up of a chemically modified tannin extract from *Acacia mearnsii* and can be used in drinking water treatment. Low coagulant doses resulted in high algal removal percentages, and operating conditions of neutral pH and room temperature allowed up to 80% algae removal with only 5 mg L^{-1} of coagulant. For water clarity, Acquapol C1 was found to be more effective than aluminium sulphate, a classical metal salt.

Natural coagulants based on tannin were used to treat the water (Thakur and Choubey [2014]). The coagulant properties of tannins from *Acacia catechu* were investigated. The surface water sample was tested for turbidity and other physicochemical characteristics. The findings showed that at the optimum dose of 3.0 mL L^{-1}, *Acacia catechu* powder could eliminate turbidity up to 91% and total dissolve solids (TDS) by 57.3 percent, but other parameters could not be eliminated.

Silvafloc, a tannin-based coagulant, was used to clarify surface river water (Sanchez-Martin et al. [2010a], [b]). A chemically modified tannin extract from *Schinopsis balansae*, also known *as* Quebracho colorado, was used as the coagulant. With 20 mg L^{-1} of coagulant and neutral pH and room temperature operating conditions, 90% turbidity was removed. The treated water had a low polyphenol content (0.4 mg L^{-1}) and was free of organic matter (30%). Silvafloc was found to be a more effective coagulant than aluminium sulphate, a traditional metal salt for water clarification. It is suitable for the treatment of drinking water. Silvafloc, may be the reaction product of three reagents: monoetanolamine (MEA) formaldehyde and the tannin extract mixture.

Conclusion for future biology

The possible use of tannin-based coagulants as a replacement for conventional chemical coagulants in wastewater and water treatment was evaluated in this study. Coagulants derived from tannin-bearing plant sources have been studied extensively, and their potential for use in water and wastewater treatment has been identified. They also achieved impressive results in the elimination of contaminants like heavy metals, total nitrogen, COD, turbidity, and total suspended solids from wastewater. The eco-friendliness of these products has been well established and they have paved the way for the implementation of clean, green chemistry, healthy, and cost-effective technology. Tannin-based flocculants can, in reality, be used to replace chemical flocculants, which have been shown to have negative effects on the environment and human health. Many tannin-based flocculants showed substantial flocculating behaviour on a laboratory scale, with pollutant removal efficiency exceeding 90% depending on the type of modified tannin used to treat the water and wastewater. To optimize the procedures for each form of wastewater, extensive research is needed. Finally, the effectiveness of tannin-based coagulants should be tested on a commercial scale in real-world scenarios for a range of wastewater systems, accompanied by a techno-economic study. This review aimed to provide a detailed overview of the most efficient, cost effective, eco-friendly

tannin-based coagulants, and the multiple applications in removal of various pollutants from different types of wastewaters.

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FPGA design of arithmetic optimised APT-VDF using reusable Vedic multiplier with simplified combinational logics for medical signal denoising

N. Alivelu Manga, G. Pradeep Kumar & **V. Satyanarayana Tallapragada** ✉

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ABSTRACT

All-pass transformation (APT)-based variable digital filters (VDFs) can be used in different biomedical signal-processing applications, particularly in electrocardiograph denoising. In this paper, arithmetic optimised APT-VDF is proposed by modifying the hardware structure of APT-VDF based on arithmetic perception to enhance the performance in terms of area, speed and power consumption. The core blocks of the suggested Arithmetic Optimised APT-VDF (AOAPT-VDF)are adders and multipliers. This paper introduces a new reusable Vedic

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A Low-Profile Multifunctional Metasurface Reflector for Multiband Polarization Transformation

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Abstract—This brief proposes a low-profile multifunctional metasurface reflector for simultaneous linear to linear (LP-to-LP) and linear to circular (LP-to-CP) polarization conversion over multiple bands. The metasurface unit cell comprises a split ring resonator-loaded cross-diagonal pattern printed at the top of a dielectric substrate and a thin air space that separates the metallic bottom plate. The proposed reflector exhibits tri-band LP-to-LP conversion at 5.47-5.68, 7.86-8.84, 14.68-16.83 GHz, and quad-band LP-to-CP conversion at 5.30-5.41, 5.77-7.58, 9.27-13.91, 17.53-19.59 GHz frequency range. The response of the surface is analyzed through an equivalent circuit model (ECM), which gives physical insight into the metasurface. Moreover, the metasurface is explored through the characteristics mode (CM), where significant modes are determined based on the modal behaviors. Thereafter, modal behaviors are further investigated for simultaneous linear and circular polarization. Furthermore, the proposed structure and its mirror symmetric configuration are employed to develop the checkerboard surface. Such surface essentially realizes the phase gradient mechanism, which results in radar cross-section (RCS) reduction in the frequency range of 5.85-5.95, 9.2-10.3, and 16.6-18.5 GHz. The measured results are in good agreement with the simulated response.

Index Terms—Multifunctional metasurface, circular polarizer, linear polarizer, equivalent circuit, characteristic mode.

I. INTRODUCTION

IN RECENT times, the metasurface has gained significant attention due to its ability to control electromagnetic wave behavior. Therefore, researchers have taken a keen interest in developing metasurface to control the polarization in transmissive and reflective modes [1]. However, the transmissive polarization converter suffers from narrow bandwidth due to its resonant behavior, while the reflective metasurface can achieve broader bandwidth by its anisotropic structure [2]. Thus, the reflective type polarization converter has been recently studied extensively. In [3], [4] anisotropic reflective surfaces have been presented to produce LP-to-LP conversion with wideband feature. In [5] an ultrawideband (UWB) LP-to-LP converter was developed using slotted ellipse-shaped structure. Besides, several unique structures like dual split ring resonator [6], cut-wire structure [7] for dual-band LP-to-LP conversion were

proposed. Apart from LP-to-LP, several LP-to-CP converters have been developed recently. In [8] a broadband LP-to-CP converter was presented based on rectangular patch and slanted surface. Jia *et al.* proposed a superstrate and via-based structure for UWB LP-to-CP conversion [9]. However, the aforementioned converters can provide either LP-to-LP or LP-to-CP conversion, which lacks multifunctionality. In this context, it is worth mentioning that a metasurface with simultaneous LP-to-LP and LP-to-CP conversion in multiple bands is of practical relevance.

However, much less effort has been directed towards the multifunctional polarization converting metasurface. Zheng *et al.* introduced a meanderline with cut-wire structure in [10] and an H-shaped structure in [11] to realize multi-polarization conversion. However, both the designs are limited to a single band of LP-to-LP and a single band of LP-to-CP conversion. In [12] an SRR-loaded structure and, in [13] a square-shaped resonator were reported as triple-band multifunctional polarization converters where one of the band is for LP-to-LP, and the other two bands are for LP-to-CP conversion. Besides, Zheng *et al.* proposed another triple-band multi-polarization converter for dual-band LP-to-LP and single-band LP-to-CP conversion [14]. However, many advanced practical applications require multiple LP-to-LP and LP-to-CP conversion bands. In this context, Wahidi *et al.* presented a multifunctional metasurface for dual-band LP-to-CP and triple-band LP-to-LP conversion [15]. Moreover, low structural profile is also essential for practical implementation. Only a few multifunctional metasurfaces were reported with relatively low-profile structure [13], [15]. It is important to note that the multifunctional metasurface performance can be improved further by still reducing its structural profile. As a result, the multifunctional polarization converting metasurface design within a low-profile configuration requires much attention.

Recently, in another aspect of EM modeling, CM has been extensively used in the antenna domain [16], [17]. However, the analysis of artificially engineered surfaces using CM is still in infancy and restricted in the domain of absorber/rasorber [18], [19]. In this context, it is notable that the conventional approach to metasurface analysis is strongly dependent on source-based mechanisms. However, CM allows us to analyze the structure irrespective of source incidence, and to the best of our knowledge, the characteristic mode-based approach is yet to be employed in the context of polarization converter.

In this brief, to address the above-mentioned issues, a low-profile multifunctional polarization transforming metasurface has been proposed. In order to explain the physical mechanism, a conceptual equivalent circuit model has been developed. Herein characteristic mode-based approach has been employed to characterize its intrinsic features and polarization states which makes the proposed converter unique from other relevant work [10], [11], [12], [13], [14], [15]. It is worth mentioning that the proposed design shows wider LP-to-CP

Design of miniaturize flexible wideband frequency selective surface for electromagnetic shielding application

Jeet Ghosh, Rahul Dutta, Abhishek Sarkhel & Qammer H. Abbasi

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Design and Analysis of Compact Dual-Band Antenna System for Scalp and Skin Implantation

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Design and Analysis of Compact Dual-Band Antenna System for Scalp and Skin Implantation

Moirangthem Santoshkumar Singh[1], Sourav Roy[2], Jeet Ghosh[3],
Ujjal Chakraborty[4], Soumendu Ghosh[1], and Abhishek Sarkhel[1, *]

Abstract—This article proposes a compact dual-band circular-shaped implantable antenna for scalp and skin implantation applications. The proposed antenna covers the 1.395–1.432 GHz Wireless Medical Telemetry Service (WMTS) band and 2.4–2.48 GHz Industrial, Scientific, and Medical (ISM) band with a compact volume of $0.0000017\lambda_0^3$. The antenna maintains a realized peak gain of -24.5 dB and -20.6 dB, respectively, at 1.43 GHz and 2.44 GHz. Moreover, the gain pattern of the antenna is in the off-body direction which is a desirable feature for implantable scenario. It also depicts stable responses under different implantation scenarios. Moreover, the via free configuration is an advantageous feature of the proposed antenna in the context of fabrication complexity. Furthermore, a holistic design approach is considered with integrated components for device-level architecture. The resonance behavior of the proposed antenna structure is also analyzed by developing a conceptual equivalent circuit model. The evaluated specific absorption rate (SAR) complies with the regulated human safety standard. The biotelemetry link capability is also evaluated through the link margin (LM) calculation of the proposed antenna and is able to establish a communication link at a range of 4.5 m distance.

1. INTRODUCTION

The advancement in technology has considerably influenced humans' day-to-day life. In recent times, the development of biomedical devices for human health monitoring has received considerable attention [1–6]. These biomedical devices have been broadly categorized into two different categories: (1) wearable and (2) implantable/ingestible devices where the antenna has a pivotal role to play [2, 3]. Apart from wearable medical devices, researchers have taken a keen interest in the design and development of implantable medical devices (IMDs). In this regard, it is essential to note that IMDs have been developed for sensing, monitoring, stimulation, and drug delivery to improve the quality of human life [3, 4]. These devices assist in patients' diagnostic and therapeutic purposes [3]. The wireless IMDs with biotelemetry functionalities are beneficial with the integration of modern communication technology [3–5]. The wireless IMDs comprise different components, including battery, electronic circuitry, sensor, and implantable antenna.

In this context, it is worth noting that an efficient implantable antenna plays a vital role in establishing reliable communication between the IMD and external control unit. It should be noted that, unlike the traditional antenna for free-space application, designing an implantable antenna involves many challenging factors such as miniaturization, operating frequencies, specific absorption rate (SAR) for human safety, and biocompatibility with human tissue [4–6]. In this context, antenna miniaturization with desired characteristics is one of the main challenges as the space available for antenna placement in the compact implantable device is limited. In the recent past, researchers have proposed implantable

Hybrid lightweight cryptography with attribute-based encryption standard for secure and scalable IoT system

Mounika Jammula, Venkata Mani Vakamulla & Sai Krishna Kondoju

Hybrid lightweight cryptography with attribute-based encryption standard for secure and scalable IoT system

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ABSTRACT

Internet of Things (IoT) devices require lower power consumption with higher security, which can be achieved by using lightweight cryptography (LWC) approaches. Attribute-based encryption (ABE) provides a fine-grained access control policy over encrypted data, making it useful in IoT-based cloud storage for allowed data protection. However, the conventional ABE approaches resulted in poor security performance against various attacks in the IoT environment. So, in this paper, the LWC-ABE method is proposed to enhance the security performance against various attacks in the IoT environment. The proposed LWC-ABE contains only multiple trusted authority environments, which is a bottleneck in IoT servers and IoT devices. The proposed LWC-ABE method supports high expressiveness, access policy updates, large attribute domains, and white box traceability properties. The simulation results shows that the proposed LWC-ABE resulted in reduced encryption and decryption times for multi users, different message sizes scenarios as compared to conventional approaches. The numerical outcomes of the proposed method are much better based on performance of encryption and decryption times as 0.000835 and 0.000310 respectively.

1. Introduction

Recently, IoT technology and wireless communications are rapidly growing, and users have been using light-weight devices and small computing devices (Fu et al., 2022). The reasons behind this are that these devices are cheaper, smaller, more powerful, and more efficient in handling. Further, resource-constrained devices like RFID tags, contactless smart cards, smart phones, wireless patient monitoring systems, and wireless sensor networks are widely suffering from higher security issues (Rasori et al., 2022). The study of tradable investment products known as assets is known as security research. It focuses on determining the appropriate value of certain commodities (i.e. stocks and bonds). These are often categorised as either derivative contracts, equity, or a combination of the two. Shareholders also include tradable financial futures. One of the most significant changes in information and

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Distributed MAC Protocol with Game Theory Optimization for Wireless Sensor Networks

S. Radha, B. Sachin, Seyedali Pourmoafi and P. Nagabushanam

Wireless Sensor Networks face limitations in battery life, energy consumption and network lifetime. By fixing high transmission power, the scenario leads to high interference when neighboring nodes try to communicate. The interference and noise levels in the channel degrade the SNR of the signal being transmitted. In this paper, we have proposed distributed MAC with game theory optimization logic for transmission power calculation for each node. Thereby the node can set adaptively its rest, listen and alive state durations using normalized probability and pay-off matrix. Queuing function is used to calculate pay-off values using approximation method. Based on this approximation nodes get reward or penalty for its behavior in the network. Thereby interference can be monitored by setting contention window threshold and number of alive sensors can be validated. The proposed DS-MAC is simulated using NS2 and it shows better performance in metrics like average energy and end to end delay, network lifetime, Goodput compared to conventional MAC in all the environmental setup and the different scenarios we tested.

Keywords: DS-MAC (distributed MAC), Goodput, game theory optimization, pay-off matrix, energy consumption

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A novel COVID diagnosis and feature extraction based on discrete wavelet model and classification using X-ray and CT images

V.V. Satyanarayana Tallapragada[1] · N. Alivelu Manga[2] · G.V. Pradeep Kumar[3]

Abstract

Recently, the Covid-19 pandemic has affected several lives of people globally, and there is a need for a massive number of screening tests to diagnose the existence of coronavirus. For the medical specialist, detecting COVID-19 cases is a difficult task. There is a need for fast, cheap and accurate diagnostic tools. The chest X-ray and the computerized tomography (CT) play a significant role in the COVID-19 diagnosis. The advancement of deep learning (DL) approaches helps to introduce a COVID diagnosis system to achieve maximum detection rate with minimum time complexity. This research proposed a discrete wavelet optimized network model for COVID-19 diagnosis and feature extraction to overcome these problems. It consists of three stages pre-processing, feature extraction and classification. The raw images are filtered in the pre-processing phase to eliminate unnecessary noises and improve the image quality using the MMG hybrid filtering technique. The next phase is feature extraction, in this stage, the features are extracted, and the dimensionality of the features is diminished with the aid of a modified discrete wavelet based Mobile Net model. The third stage is the classification here, the convolutional Aquila COVID detection network model is developed to classify normal and COVID-19 positive cases from the collected images of the COVID-CT and chest X-ray dataset. Finally, the performance of the proposed model is compared with some of the existing models in terms of accuracy, specificity, sensitivity, precision, f-score, negative predictive value (NPV) and positive predictive value (PPV), respectively. The proposed model achieves the performance of 99%, 100%, 98.5%, and 99.5% for the CT dataset, and the accomplished accuracy, specificity, sensitivity, and precision values of the proposed model for the X-ray dataset are 98%, 99%, 98% and 97% respectively. In addition, the statistical and cross validation analysis is conducted to validate the effectiveness of the proposed model.

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Speaker Recognition Based on Mutated Monarch Butterfly Optimization Configured Artificial Neural Network

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Abstract – *Speaker recognition is the process of extracting speaker-specific details from voice waves to validate the features asserted by system users; in other words, it allows voice-controlled access to a range of services. The research initiates with extraction features from voice signals and employing those features in Artificial Neural Network (ANN) for speaker recognition. Increasing the number of hidden layers and their associated neurons reduces the training error and increases the computational process's complexity. It is essential to have an optimal number of hidden layers and their corresponding, but attaining those optimal configurations through a manual or trial and the process takes time and makes the process more complex. This urges incorporating optimization approaches for finding optimal hidden layers and their corresponding neurons. The technique involve in configuring the ANN is Mutated Monarch Butterfly Optimization (MMBO). The proposed MMBO employed for configuring the ANN achieves the sensitivity of 97.5% in a real-time database that is superior to contest techniques.*

Keywords: *Speaker recognition, Speaker verification, Speaker identification, Artificial Neural Network, Monarch Butterfly Optimization, Model configuration.*

1. INTRODUCTION

Since a decade ago, academics and industry have paid increasing attention to speaker identification [1]. It is extensively used in applications, including security and surveillance, financial security, discriminative speaker embedding learning, voice authentication, forensic voice verification for suspect detection [2], electronic voice eavesdropping, voice conversion, and identity verification, as well as access control, biometrics authentication, mobile shopping, and mobile banking [3]. It essentially involves classifying unknown speakers based on their speech [4]. Speaker identification is the process of identifying a speaker sound based on a set of trained speaker sounds. In other words, speaker identification compares one user's voice profile with many other profiles and determines the best or exact match. Since speech signals are the primary means of communication, they constantly contain rich, relevant details, such as speakers' accents, gender, emotions, and other characteristics. As a result of these distinctive characteristics, researchers can distinguish

between speakers during phone calls, even when the speakers are not physically present [6] [8] [9].

Speaker Identification involves identifying unknown voices from a fixed set of known speakers. Therefore, it is called closed set identification. Based on the speech used for identifying the speaker, the systems can be grouped into text-dependent (fixed text is used for both training and testing phase) and text-independent (no fixed text). Out of the two types, text-independent specker recognition is most challenging job. The error that can occur in speaker identification is false identification, which can be measured by sensitivity, which determines the correctness of the predictions. A high sensitivity model provides a more reliable result than a low sensitivity model in medical applications. Hence, the objective of this work is to build a model for text independent speaker recognition with improved recognition accuracy as well as sensitivity.

A variety of models, techniques, and algorithms are employed to identify speakers in recent literature, including Mel-frequency Cepstral Coefficients (MFCC)

ORIGINAL PAPER

Modified remora optimization based matching pursuit with density peak clustering for localization of epileptic seizure onset zones

B. Indira Priyadarshini[1] · D. Krishna Reddy[2]

Abstract

Epilepsy is a common neurological disorder in which the activity of brain becomes abnormal, causing sensation, loss of awareness, and periods of unusual behavior or seizures, which is recurrent in nature. In localization, high-frequency oscillations (HFOs) are spontaneous EEG patterns that have been regarded as potential biomarkers of epileptic seizure on zones (SOZs). Accurately detected HFOs are used to localize SOZs, which is crucial for the presurgical assessment. Since the visual marking of HFOs is time-consuming, a method is desirable to detect HFOs for localizing SOZs in clinical practice automatically. However, the existing techniques cannot obtain satisfactory performance, which is not suitable for clinical application. To solve this problem, a new localization method for epileptic SOZs has been proposed based on Modified Remora Optimization based Matching Pursuit with Density Peak Clustering (MRO-DC). Initially, a Stockwell entropy based on the Hilbert transform is used to detect events of interest (EoIs). In addition, a time–frequency analysis method like Shannon-entropy-based complex Morlet wavelet transform (SE-CMWT) is adopted to acquire channels of interest (CoIs) by calculating the average power of EoIs on each channel. Subsequently, a MRO-DC approach has been proposed to detect HFOs of CoIs. Finally, the concentrations of the detected HFOs are used to localize SOZs better. The proposed approach is implemented in the Xilinx working platform by instigating Verilog code. The result of the proposed approach showed that the MRO-DC had achieved maximum specificity and sensitivity on Field Programmable Gate Array (FPGA). The maximum performance of 99.4% specificity, 98.2% sensitivity, and 0.575 ns computational time is obtained while testing the FPGA to localize the epileptic SOZs.

Keywords High-frequency oscillations (HFOs) · Events of Interest (EoIs) · Hilbert transform · Shannon-entropy-based complex Morlet wavelet transform (SE-CMWT) · Field Programmable Gate Array (FPGA) and Matching Pursuit with Density Peak Clustering

1 Introduction

In the world, nearly 70 million people have been suffering from a severe disease called an epileptic seizure. The abnormal and frequent response of the human brain is named epileptic seizure disease. About 40% of epilepsy patients didn't get sufficient medical treatment. The EEG variations are determined in the human brain by putting electrodes on the scalp of the brain. The EEG signal output has greater empathy to the brain signal. So that EEG is utilized for seizure detection and diagnosis of the person. Currently, epilepsy diagnosis is found by observing and examining the electroencephalogram (EEG) value since the event of epileptic seizures can be perceptible in the frequency spectrum of the EEG signals. This issue can be defeated by scheming mechanized seizure finding devices. The seizures occur due to abnormal situations and disturb the usual character of the brain. Before clinical manifestation, the popular technique to detect the onset of a seizure is normally through the analysis of scalp electroencephalogram (EEG). EEGs are fetching progressively main quantification of brain pursuit and have higher energy for identifying and treating seizures and abnormalities (Sanei).

With a suitable explanation, the recent techniques are forming more significant to decrease the enlarging global

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A Hybrid Classification Approach for Iris Recognition System for Security of Industrial Applications

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The biometric authentication system is demanded to identify a particular person from the set of persons. Even though many biometric authentication methods are available such as fingerprint, palm, face, and iris, the iris-based recognition system is effective due to its simplified process. This article proposes an iris recognition system using a hybrid classification approach for security applications. The proposed method includes three modules: preprocessing, augmentation, and classifier. The preprocessing module converts the color iris images into grey scale images and also resizes the image into 256×256. The preprocessed iris images are now data augmented to construct the larger dataset. The data augmented images are classified into either genuine or imposter images using a hybrid classification approach. The hybrid classification approach functions in two modes as training and testing. In this article, the Convolutional Neural Networks (CNN) is integrated with the Adaptive Neuro-Fuzzy Inference System (ANFIS) classifier to enhance the recognition rate of the iris recognition system. The performance analysis of the proposed approach is shown in terms of sensitivity, accuracy, recognition rate, specificity, false-positive rate, and false-negative rate. The experimental results of the proposed iris recognition system stated in this article significantly outweigh other design methods.

Introduction

A biometric authentication system is used to identify persons using biometrics methods such as fingerprint, palm, facial expression, and iris. Among these biometric authentication systems, Iris Recognition (IR) is one biometric authentication method for identifying a particular person among the set of persons in a region. This biometric authentication uses iris images that are captured by Charge Coupled Camera (CCC) or mobile phone. The iris-based recognition system uses ring-shaped patterns of iris images to identify individual persons.[1-5] Scanners or scanning devices are most important for the iris-based person identification system. In this modern era, high-resolution scanning devices are used to capture iris images without damaging the internal tissues of the human eye. The iris recognition system is complex compared with other biometric recognition systems such as the face, fingerprint (Fig. 1-(a)), and palm print (Fig. 1-(b)). These conventional biometric authentication systems use a large portion of the human part. Hence, it is easy

to recognize the image for authentication purposes. In the case of the iris recognition system (Fig.1-(c)), only a small portion of the human eye is involved in the recognition process, which makes the recognition system more complex.[6-10]

This article uses soft computing techniques to overcome the limitations produced by convolutional methods. Two soft computing techniques are deep learning and machine learning. This paper integrates a deep learning algorithm with the machine learning algorithm to enhance the iris recognition rate.

Literature Survey

Ghosh *et al*.[11] used machine learning algorithms such as a linear classifier to recognize individual iris images. The authors obtained 94.7% of Sensitivity (Se), 90.6% of Specificity (Sp), 91.9% of Accuracy (Acc), 12.8% of False Positive Rate (FPR), and 8.7%

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Fig. 1 — (a) Fingerprint image, (b) Palm image, (c) Iris image

ORIGINAL PAPER

Adaptive octopus deep transfer learning based epileptic seizure classification on field programmable gate arrays

B. Indira Priyadarshini[1] · D. Krishna Reddy[2]

Abstract
Seizures are a type of neurological illness that can disrupt the processes of the human brain. In most cases, epileptic abnormalities may be detected with direct visual scanning. However, owing to various technical artefacts, this scanning takes more time and is limited. As a result, an effective deep learning-based computer-aided diagnosis system for automatically differentiating seizure signals from non-seizure signals is required. Even if the classification accuracy of deep learning algorithms is sufficient, executing them on field programmable gate arrays (FPGA) is computationally quite expensive. In this paper, a new adaptive octopus deep transfer learning (AODTL) based epileptic seizure classification model is proposed to identify the best trade-off between the classification accuracy and hardware complexity. The proposed model selects the most significant features from the scalogram images using jellyfish search optimizer. Also, it fine-tunes the hyper-parameters automatically using the octopus optimizer. These optimizers are used to reduce the number of parameters required for the proposed AODTL classifier, so that the computational complexity is reduced. The implementation of the proposed work is carried out in Xilinx working platform and validated on the Temple University Hospital Seizure Detection Corpus (TUH EEG) database. Finally, the result of the proposed method showed that the diagnosis and classification of deep transfer learning model with maximum accuracy can be accomplished on FPGA. The maximum performance of 99.48% accuracy, latency of 6.1 ms, slice LUTs of 898 and power of 1.043 µW are achieved when testing on the FPGA board for classifying the epileptic seizures.

Keywords Epileptic seizure · Jellyfish search optimizer · Adaptive octopus algorithm · Feature extraction · Finite impulse response filter · Continuous wavelet transform and field programmable gate arrays (FPGA)

1 Introduction

One of the most harmful nervous system disease is epilepsy, which is a chronic disease featured by two seizures namely unprovoked and recurrent seizures. The World Health Organization (WHO) stated that nearly 50 million people are suffered in the world due to this seizure disorder and 75% of affected people live in an economically backward countries (Li et al. 2017). In addition, 4–10 people out of 1000 were affected by this active epilepsy globally. On the other hand, this proportion is much varied for the people from economically backward countries (i.e., 7–14 people per 1000 people). Due to the massive prevalence of this disorder, proper detection and appropriate regimen are required. In recent years (Alzami et al. 2018), the Electroencephalogram (EEG) is a significant clinical tool assists to monitor, diagnose and manage the epilepsy-related neurological diseases (Li and Yang 2017). Due to its potential, correct and adequate efficient strategy, the EEG is used to understand the spatial and temporal information of the electrical voltages of the brain (Bhagat et al. 2019; Ahmadi et al. 2017a, b).

Moreover, it is applied to recognize the affected people by locating electrodes on the surface of skull. The feature signatures patterns for seizures are included in these EEG records that help the neurologists to detect the disease. However, several challenges are there in EEG such as processing difficulty, repetitive activity and take more than an hour for a single patient (Alzami et al. 2018).

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Research Article

Light-Weight Clustered Trust Sensing Mechanism for Internet of Things Network

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❝ Download citation   ↗ https://doi.org/10.1080/03772063.2022.2130449

Abstract

In recent years due to technological advancements, the Internet of Things (IoT) has been continuously shaping the way to interact with the world around us in homes, workplaces and in different aspects of our life. However, the IoT is an infrastructure-less network and used for long-distance communication, the IoT nodes seek the help of other nodes for effective communication and information transfer. In IoT network, secure communication is the prime concern because of the open internet source and heterogeneity which offers challenges to the network. To achieve efficient security in the IoT devices and to make the IoT network more resilient to different attacks there is a need to design a secure framework to make the IoT more secure against several security threats. Trust Sensing has been playing a significant role in dealing with security issues. A new Light Weight Clustered Trust Sensing

(LWCTS) Mechanism is developed which mainly aims at the reduction of energy consumption of IoT nodes. Initially, the LWCTS clusters the network and chooses Cluster Heads that are rich in resources. Furthermore, the proposed trust model considers two factors: Interactive trust factor and the mobility factor for trust sensing. The mobility factor involvement is mainly implemented to reduce the false positive count in the network. Simulation experiments are conducted over the proposed model and the performance is measured with Malicious Detection Rate, False Negative Rate, False Positive Rate, Average Energy Consumption, and Packet Delivery Ratio. The obtained results prove the effectiveness when compared with existing approaches.

🔍 **KEYWORDS:** Clustering   Internet of things   Malicious Detection Rate   Mobility

Packet Delivery Ratio   Packet forwarding factor   Trust sensing

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ORIGINAL PAPER

Implementation of receiver autonomous integrity algorithm for fault detection of IRNSS

D. Sony[1] · D. Krishna Reddy[1] · P. Naveen Kumar[2]

Abstract
Indian Regional Navigation Satellite System (IRNSS) has been developed by Indian Space Research Organization (ISRO), to provide the positioning services to the users of the system over Indian region. However, IRNSS does not provide any integrity warning of the system malfunctioning. Moreover, the satellites of the system are susceptible to faults due to various errors. To monitor the integrity of the position estimate, the faults associated with satellite malfunctioning also have to be detected and carried out at the receiver by developing a suitable Receiver Autonomous Integrity Monitoring (RAIM) technique for fault detection of IRNSS satellites. In this paper, an attempt is made to implement least square (LS) residual-based RAIM for fault detection of IRNSS satellites. LS-based RAIM is robust and used to successfully detect IRNSS satellite measurement faults. The test statistics and test threshold are evaluated from the data acquired from the IRNSS-GPS-SBAS (IGS) receiver installed at (17.39° N, 78.31° E) CBIT Hyderabad. It is observed that there is a maximum variation in Horizontal Protection Limit (HPL) ranging from 8 to 172 m for 1F assumed as faulty satellite of IRNSS.

Keywords Receiver Autonomous Integrity Monitoring · Horizontal protection limit · Alert limit · Least square residual method · Fault detection

Abbreviations

GNSS   Global Navigation Satellite Systems
IRNSS Indian Regional Navigation Satellite System
ISRO   Indian Space Research Organization
RAIM   Receiver Autonomous Integrity monitoring
FAR   False alarm risk
MDR   Missed detection risk
LS   Least square
LSR   Least-squares residual
HPL   Horizontal protection limit
GSO   Geosynchronous orbit
GEO   Geostationary orbit
SPS   Standard Position Services
RS   Restricted Service
HAL   Horizontal alarm limit
TTA   Time to alert

DOP   Dilution of precision
GDOP   Geometric dilution of precision
SAC   Space Applications Centre

1 Introduction

IRNSS is an independent navigation satellite system developed by ISRO. The IRNSS constellation has IRNSS- 1A, 1B, 1C, 1D, 1E, 1F, 1G and 1I satellites on orbit. Five of them are (1A, 1B, 1D, 1E and 1I) are placed in geosynchronous orbit (GSO) and the remaining satellites (1C, 1F and 1G) are in geostationary orbit (GEO). The satellite 1A was atomic clock failure and 1H was launch failure. IRNSS provides two types of services namely Standard Position Services (SPS) and Restricted Service (RS). The signals of IRNSS are transmitted on L5 (1164.45–1188.45 MHz) and S (2483.5–2500 MHz) bands.

IRNSS comprises three segments, namely the space segment, the control segment, and the user segment. Space segment consists of all the satellites which broadcast signals to the user segment. The control segment includes master stations, data upload stations, and monitor stations and the user

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Article

Evaluating the Efficiency of Non-Orthogonal MU-MIMO Methods in Smart Cities Technologies & 5G Communication

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Abstract: Many cutting-edge technologies, such as MIMO, cognitive radio, multi-carrier modulation, and network coding, have been proposed for wireless communication to satisfy needs for a higher data rate in the upcoming time, leading to improved quality of service (QoS) regardless of the weather. Orthogonal and non-orthogonal multiple access techniques are two categories into which multiple access technologies can be subdivided. Large networking with effective implementation of wireless devices is supported by non-orthogonal multiple access techniques. Massive NOMA has been implemented to advance access efficiency by permitting several users to share a similar spectrum. Because of the robust co-channel interference between mobile users presented by NOMA, it offers important tasks for system model and resources management. In this study, two additional sets of demanding codes are explored. Multi-user shared access methods and expanded multi-user shared access (EMUSA) methods are both employed. In the MUSA technique, an algorithm is used for the allocation of resources to achieve minimum intercorrelation to the maximum extent in 5G networks. A novel idea proposed in this paper is to create complex codes starting from PN codes (i.e., ePN), thereby achieving promising results in the overall system performance. The first part of this paper describes the fundamental principles of MUSA, and in the next part the main idea of the proposed technique will be studied in detail. Using Monte-Carlo MATLAB simulation, the performance of the suggested approach is assessed in terms of BER vs. SNR. The efficiency of the proposed approach is evaluated in various settings, and the outcomes are contrasted with those of the traditional CDMA technique, using parameters, such as the number of active users and antennas at the receiver.

Keywords: ubiquitous; next generation wireless systems; 5G networks; CDMA; MUSA; OFDM and complex spreading codes

1. Introduction

The major challenge of future communication networks is to handle the gigantic data traffic that is expected in near future and very low latencies of the order of *ns* [1,2]. This is due to both the fast-expanding user base that contributes to data traffic and the ongoing development of multimedia online apps. One more important parameter of any communication network is to maintain a very good quality of service (QoS) flexibility to future requirements. To meet the above-mentioned requirements along with higher spectral

Applying machine learning enabled myriad fragment empirical modes in 5G communications to detect profile injection attacks

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Vinodh Kumar Minchula[5] · Sachin Sharma[6] · Arfat Ahmad Khan[7] · V. Prashanth[8]

Abstract

In order to facilitate communication, wireless networks are built from a collection of nodes that may be either static or dynamic. They are acquiring a lot of popularity in the area of research due to the fact that they are ad hoc in nature, and the number of users of mobile devices is rising day by day. Because of the ease with which these networks may be deployed in challenging and unsupervised rural places, the exchange of information has been a reality since the invention of these networks. Mobile ad hoc networks are simple to set up because of the properties that allow for self-organization and the fact that the medium is wireless. A lack of centralized fixed infrastructure, flexibility to frequent change in topologies, and other features like these are some of the other things that draw people's attention to wireless networks. Wireless networks are vulnerable to a wide range of assaults since their nodes are able to move around and their topologies are constantly changing. In addition, MANET operates in an environment that is both open and dynamic, which leaves it subject to a variety of threats from other types of network assaults. Routing protocols are almost always the target of one form or another of the same general category of attacks. Eavesdropping, causing damage, changing routing information, deleting routing information, manipulating information, advertising phoney routes, and misrouting information are all potential components of these assaults. The circumstances may make it difficult to maintain confidentiality in any communications. There are many different kinds of assaults, and each one may damage wireless networks on a different tier of the communication stack and bring the performance of the network down. Eavesdropping, jamming, traffic analysis and monitoring, denial of service attacks, grey hole attacks, black hole attacks, and wormhole assaults are a few examples of the many sorts of attacks that fall under this category. Ad-hoc networks are more susceptible to security breaches than traditional wired and wireless networks due to the usage of open wireless medium, dynamic topology, and dispersed and cooperative channel sharing. The wormhole attack on dispersed wireless networks is being described here by the person who conducted this study. Because this assault is so potent, it is very difficult to identify it before it has ever been launched. The invader may simply initiate it without having knowledge of the network or compromising any authorized nodes, which is a need for launching it. During a wormhole attack, a malicious node in one part of the network takes control of the packets and tunnels them to another hostile node in a different part of the network, which then repeats the packets locally. The thesis aims to do two things at the same time: (a) To simulate a variety of possible wormhole assaults on the MANET network (b) To investigate the functionality and efficiency of the proposed secure routing protocol within the context of these simulated attacks on the network.

Keywords 5G communication · Feature extraction · Improved support vector classification · Profile injection attack detection

1 Introduction

The study of mobile ad hoc networks is becoming more important in the realm of research, in addition to being a subject that is gaining popularity in the industry. Mobile ad hoc networks have become an appealing choice of technology as a result of the proliferation of applications that may be used in a variety of contexts. Despite this, the characteristics of ad hoc networks, such as self-administration and changeable network topology, provide unique security challenges [1]. Mobile ad hoc networks have become an appealing choice of technology as a result of the

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Full length article

MaReSPS for energy efficient spectral precoding technique in large scale MIMO-OFDM

Arfat Ahmad Khan [a] ✉ , Khalid K. Almuzaini [b] ✉ , Víctor Daniel Jiménez Macedo [c] ✉ , Stephen Ojo [d] ✉ , Vinodh Kumar Minchula [e] ✉ ,
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Abstract

Spectral pre-coding is a capable method to restrain Out-Of-Band Emission (OOBE) and act in accordance with leaking parameters over neighboring frequency channels while masking unnecessary emissions. Nevertheless, spectral pre-coding might deform the real data vector that is articulated as the Error Vector Magnitude (EVM), which shows a harmful effect on the performance of Multiple-Input Multiple-Output-Orthogonal Frequency Division Multiplexing (MIMO-OFDM)-oriented schemes. In this research, a new Mapper Reducer for spectral pre-coded signal (MaReSPS) for energy-constrained signal receiver is proposed for energy efficient spectral precoding in the MIMO-OFDM system. This model involves Mapper Reducer (MR) framework for detecting the received signal, which renders an error rate, and graceful degradation is observed in the throughput under channel uncertainty. The proposed scheme alleviates the resultant Transmit EVM (TxEVM) observed at the receiver by capitalizing on the massive MIMO system, and as a result the throughput is improved. The comparison is done with respect to Block Error Rate (BLER), throughput, and Power Spectral Density (PSD) for proving the betterment of the proposed precoding model for MIMO-OFDM. In particular, the normalized throughput for conventional No OOBE Reduction (OOBER), Mask Compliant Spectral Pre-coder (MSP), Notching Spectral Pre-coder + Zero Forcing (NSP + ZF), P1/P2: CVX and P1/P2: Top-Alternating Direction Method of Multipliers (ADMM) models, as well as proposed MaReSPS model, is lower at a Signal to Noise Ratio (SNR) from 0dB to 15dB. With an increase in SNR, the normalized throughput increases and when SNR =40dB, the normalized throughput values reach their peak values. However, compared to existing models, the proposed MaReSPS model showed high normalized throughput.

Introduction

Recently, the emerging wireless communication system has increased the demand for greater system capability by indulging in 5G mobile communication network technologies [1], [2], [3]. Its benefits are larger system capability [4], [5], [6], spectrum with free license, lower power utilization, higher security, and stronger resistance to EMI. It has steadily turned out to be a well-known technology for shorter range wireless communication methods [7], [8]. The diverse characteristics of OFDM [9], [10], [11] are equalization, simplified, adaptive transmission, extendable multiple access, flexibility in low and high symbol rates, and supports several QoS requirements [12], [13], [14].

In multipath propagation, OFDM [15] enables the frequency selective fading channel by converting it into a number of parallel flat fading channels and so, reduction in equalization and symbol decoding are complex ones [16], [17], [18]. In OFDM systems, the most important drawbacks are responsive to phase noise and offset frequency, however, the intricacy is lower due to its data undependable optimization crisis and OOBE suppression is excellent. Unfortunately, for 5G implementations, the usage of AIC-type OOBE reduction methods is irrelevant to acting in accordance with NR specifications [19], [20], [21]. Reduction in OOBE results in stringent spectrum efficiency because the exploitation of active data subcarriers is done without sacrificing the cyclic prefix, thereby spectral pre-coding is the challenging one for reduction in OOBE. Before OFDM modulation, spectral pre-coding of data symbols reduces the OOBE without increasing the time/delay dispersion or the cyclic prefix of the transmitted signal [22], [23], [24].

Article

A Novel Integrated UWB Sensing and 8-Element MIMO Communication Cognitive Radio Antenna System

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Abstract: In this article, a cognitive radio (CR) integrated antenna system, which has 1 sensing and 24 communication antennas, is proposed for better spectrum utilization efficiency. In the 24 communication antennas, 3 different operating band antennas are realized with an 8-element MIMO configuration. The sensing antenna linked to port 1 is able to sense the spectrum that ranges from 2 to 12 GHz, whereas the communication 8-element MIMO antennas linked with ports 2 to 9, ports 10 to 17 and ports 18 to 25 perform operations in the 2.17–4.74 GHz, 4.57–8.62 GHz and 8.62–12 GHz bands, respectively. Mutual coupling is found to be less than -12 dB between the antenna elements. Peak gain and radiation efficiency of the sensing antenna are better than 2.25 dBi and 82%, respectively, whereas the peak gains and radiation efficiencies of all communication antennas are more than 2.5 dBi and 90%, respectively. Moreover, diversity characteristics of the MIMO antenna are assessed by parameters such as DG, ECC and CCL. It is found that ECC and CCL are less than 0.42 and 0.46 bits/s/Hz, respectively, and also DG is more than 9.1 dB.

Keywords: CCL; cognitive radio; DGG; ECC; MIMO; spectrum sensing; spectrum utilization efficiency

1. Introduction

In the licensed spectrum, channels are unutilized most of the time, thus leading to inefficient spectrum utilization. Hence, spectrum utilization efficiency deteriorates. The unutilized channels (i.e., licensed) can be used effectively for other applications to reduce the wastage of spectrum issue. CR technology mainly uses the concept of using the unutilized channels in the spectrum overlay approach. It is believed that the primary users in the spectrum overlay approach are the owners of the licensed spectrum and do not utilize their channels in the licensed spectrum completely. So, there exists a continuous monitoring in the radio environment to find the white spaces (i.e., spectrum holes). When a white space is detected at any moment, secondary users can use the channel that consists of the detected white space for other applications until the primary users want to use that channel. When primary users use that channel, secondary users should shift to any other unutilized licensed channels.